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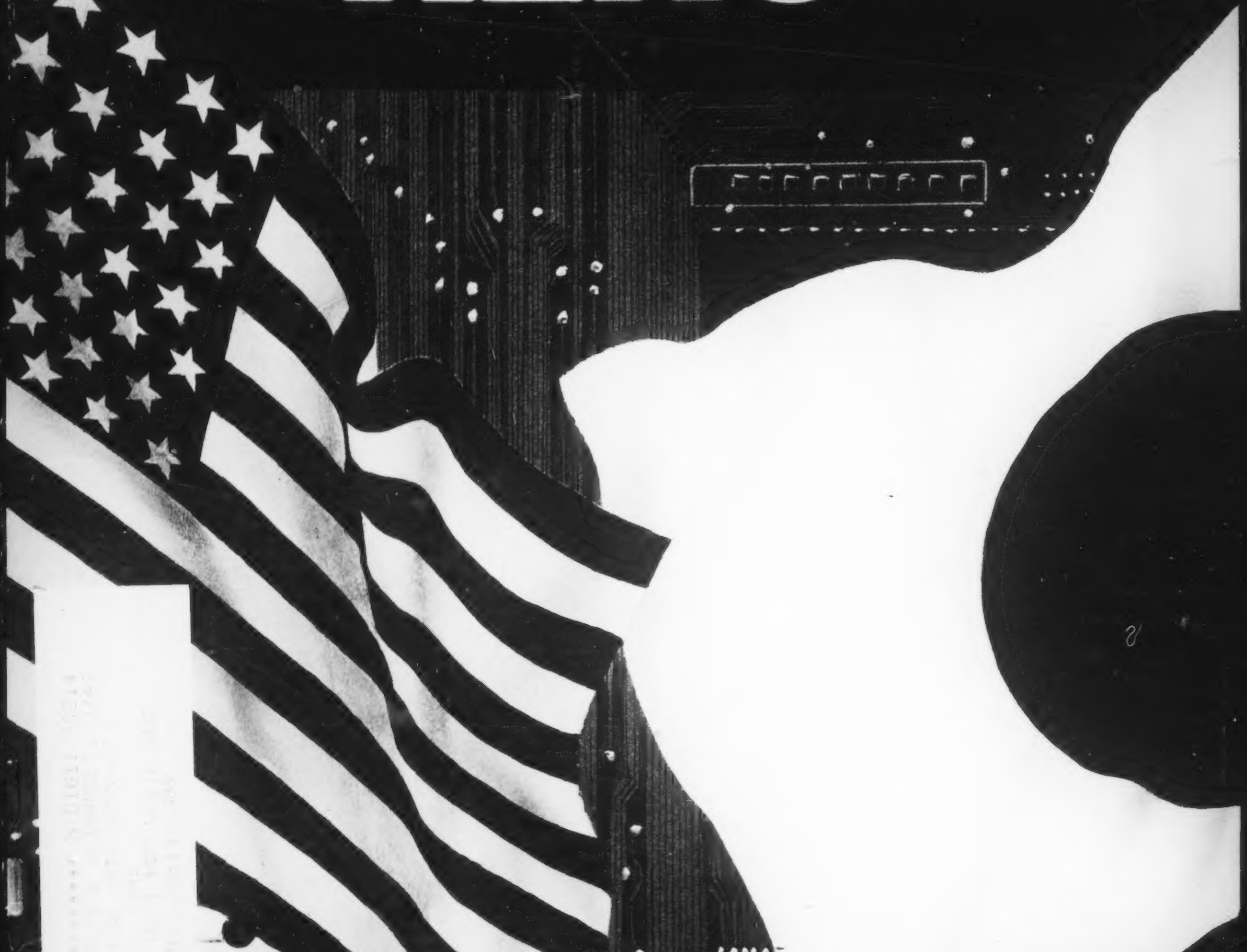
NOVEMBER 5, 1990

CHEMICAL & ENGINEERING NEWS



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CENEAR 68 (45) 1–60
ISSN 0009-2347

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Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director
Robert H. Marks, Director, Publications Division

PUBLISHING BOARD: Jean'ne M. Shreeve *(Chairman); Board of Directors Chairman:* Joseph A. Dixon; *President:* Paul G. Gassman; Richard L. Deming; William P. Jencks; Gary J. Long; and Louis D. Quin

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Subscription Rates 1990. Printed editions: nonmembers U.S. 1 yr. $60, 2 yr. $108, outside U.S. 1 yr. $93, 2 yr. $174. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $9.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

CHEMICAL SAFETY

A carbodiimide eye irritant

An undescribed aspect of a well-known hazard can sometimes be as harmful as the hazard itself. Such was the case recently for the chemical diisopropylcarbodiimide, an activating agent used in amino acid coupling reactions.

The accident occurred when a 1-L bottle of the above liquid broke in a shipping department. Donned with respirators, lab coats, and impervious gloves, a fellow worker and I volunteered to clean up the liquid spill from a desk and surrounding floor area. The total cleanup took 45 minutes to an hour and was uneventful.

Approximately 12 to 18 hours later, the effects of the exposure to the vapors began to be apparent. Hazy vision occurred the next morning followed by the onset of mild pain four hours later. The pain maximized 34 hours after the exposure. The corneal damage was limited to the outer layer, but resulted in temporary blindness and an initial visual acuity of 20/200. Sight was gradually restored over a two-week period. The insidious nature of this chemical is currently not described in the material safety data sheets. The MSDS clearly describes irritation as a result of contact of the chemical with the eyes, but mentions nothing of a delayed effect resulting from exposure to its vapors.

All who contemplate working with this compound class must be aware of the delayed effect that may be encountered. This knowledge will provide time between exposure and its effects for proper first aid measures to be initiated.

Ronald C. Moyer
Tuxedo, N.Y.

Shortage of chemists

Enough already! Your article (C&EN, Aug. 20, page 19) about the imminent shortage of scientists in chemistry, and other hard sciences, rings just as false as the last dozen or so that have appeared, particularly when the accompanying article on the status of the chemical industry is studied. Everyone seems to be in agreement that "we" should be graduating more technical people to stay competitive in the world economy. However, "we" also have to employ all these scientists and engineers—a practical problem that never seems to be addressed.

I have tried to appreciate the factors that will create the coming shortage, but can't. The U.S. is in the midst of a slump in the chemical and aerospace industries. Government funding of academic research and government research facilities is declining now, and is highly likely to shrink in the next 10 years, not grow. If the economy slides into recession, more jobs will be lost, and a big expansion of the technical sector is even more unlikely. Coupled with this, every technical person I know is having a heck of a time either finding a job (hearing of hundreds of applicants for the same position is not uncommon) or is worried about being laid off.

That issue of C&EN also presented some interesting facts: Annual change in the number of employed R&D scientists has slowed, from 6% per year to 2% per year. Annual change in people employed in industrial chemicals went down 2% from 1988 to 1989 and was an impressive 0% per year for the past 10 years! Does this data extrapolate to an impending shortage?

There are very few ads in C&EN for permanent employment (postdocs and other temporary employment seems to fare slightly better), particularly in industry. I get several unsolicited letters a month from candidates in search of work.

Looking at demographics, it appears that a large number of baby-boomer-aged scientists, now mostly graduated and out in the work force, have an average of 25 or so years to go in their careers, so I don't see any immediate surge in openings.

Without being privy to the "now-familiar numbers" that are forcing everyone to come up with creative plans to

Correction

- Sept. 24, page 10: In the table on pesticides affected by Proposition 128, oxadiazon and paradichlorobenzene should have been designated EPA group C carcinogens.

Europe dominates global chemical sales

The U.S. has more large chemical producers than any other nation, but it is Europe that dominates worldwide chemical sales.

These are two of the major findings from C&EN's first ranking of the world's 50 largest chemical producers. The ranking, based on 1989 chemical sales, augments the publication's annual listing of the 100 largest U.S. chemical producers (C&EN, May 7, page 27). For both rankings, chemical sales include most basic and downstream chemical products, but exclude pharmaceuticals.

The $310 billion total of chemical sales by the 50 largest producers worldwide indicates the huge size of the global chemical industry. In terms of company location, the U.S. has 18 producers on the list. Japan follows with 10, Germany five, France three, and the U.K., Italy, Switzerland, and the Netherlands two each. Belgium, Norway, Finland, and Saudi Arabia each are represented by one company. Two producers are jointly headquartered: the U.K.-Netherlands-based Shell Oil and Unilever.

However, if Europe is taken as a whole, it is the largest chemical-producing area, with 21 producers totaling more than $167 billion in chemical sales, or 54% of the total sales of the 50 firms. German firms alone reported chemical sales of $60.7 billion, 36% of the European total and almost 20% of the worldwide total of 50 companies.

The 18 U.S. companies in this ranking account for $97.8 billion in chemical sales, or 32% of the total. Japan's 10 firms, with an aggregate $41.3 billion, account for 13% of the total. The only company outside these three areas, Saudi Arabia's Saudi Basic Industries Corp. (SABIC), had chemical sales of $3.63 billion, or a little more than 1% of the total.

Germany's BASF is ranked as the largest producer, with chemical sales last year of $17.12 billion. The U.K.'s ICI ran a close second, with $16.97 billion. Du Pont, the largest U.S. producer, ranked fourth with chemical sales of $15.25 billion.

Patricia Layman, William Storck

Germany, U.S. each place three companies in top 10 of world's 50 largest chemical producers

Rank 1989		Chemical sales ($ millions)	Chemical sales as % of total	Chemical operating profits ($ millions)	Chemical operating profit margin[a]
1	BASF (Germany)	$17,122	60.4%	na	na
2	ICI (U.K.)	16,970	78.6	$1638	9.7%
3	Hoechst (Germany)	16,400	67.2	989	6.0
4	Du Pont (U.S.)	15,249	42.9	2769	18.2
5	Bayer (Germany)	14,810	64.3	1303	8.8
6	Dow Chemical (U.S.)	14,179	80.6	3543	25.0
7	Shell Oil (U.K., Netherlands)	11,921	11.2	1592	13.3
8	Enimont (Italy)	11,186	100.0	539	4.8
9	Exxon (U.S.)	10,559	11.1	1609	15.2
10	Rhône-Poulenc (France)	9,164	80.0	874	9.5
11	Union Carbide (U.S.)	7,962[b]	91.1	1225	15.4
12	Degussa (Germany)	7,637[c]	100.0	180	2.4
13	Ciba-Geigy (Switzerland)	7,288	58.0	na	na
14	Solvay (Belgium)	7,055	100.0	742	10.5
15	Asahi Chemical (Japan)	6,377[d]	100.0	241[e]	na
16	Elf Aquitaine (France)	6,125	21.6	na	na
17	Monsanto (U.S.)	5,782	66.6	929	16.1
18	British Petroleum (U.K.)	5,743	11.8	885	15.4
19	Akzo (Netherlands)	5,486	62.1	458	8.3
20	Mitsubishi Kasei (Japan)	5,307[d]	100.0	131[e]	na
21	Occidental Petroleum (U.S.)	5,203	25.9	1235	23.7
22	Norsk Hydro (Norway)	5,121	53.3	350	6.8
23	General Electric (U.S.)	4,929	9.0	1057	21.4
24	Huels (Germany)	4,787	100.0	364[e]	na
25	DSM (Netherlands)	4,516	88.9	574	12.7
26	Sumitomo Chemical (Japan)	4,363	100.0	146[e]	na
27	Amoco (U.S.)	4,272	17.8	744	17.4
28	Takeda Chemical (Japan)	4,262[d]	100.0	272	na
29	Montedison (Italy)	4,141	100.0	713[e]	17.2
30	Mobil (U.S.)	4,039	7.3	714	19.2
31	Sekisui Chemical (Japan)	4,018[d]	100.0	172[e]	na
32	Toray Industries (Japan)	3,982[d]	100.0	228[e]	na
33	Showa Denko (Japan)	3,811	100.0	97[e]	na
34	Saudi Basic Industries (Saudi Arabia)	3,634	100.0	899[e]	na
35	Orkem (France)	3,596	100.0	468	13.0
36	Eastman Kodak (U.S.)	3,522	19.1	643	18.3
37	Dainippon Ink & Chemicals (Japan)	3,407[d]	62.0	62[e]	na
38	Chevron (U.S.)	3,328	10.4	532	16.0
39	Hoffmann-La Roche (Switzerland)	3,280	54.8	na	na
40	W. R. Grace (U.S.)	3,256	53.2	406	12.5
41	Allied-Signal (U.S.)	2,993	25.1	355	11.9
42	Mitsui Toatsu Chemicals (Japan)	2,977[d]	100.0	87[e]	na
43	Unilever (U.K., Netherlands)	2,948	13.2	390	13.2
44	Mitsubishi Petrochemical (Japan)	2,795	100.0	228[e]	na
45	Arco Chemical (U.S.)	2,663	100.0	580	21.8
46	Rohm & Haas (U.S.)	2,661	100.0	440	16.5
47	Air Products (U.S.)	2,481[b]	93.9	425	17.1
48	Phillips Petroleum (U.S.)	2,449	19.8	652	26.6
49	Kemira (Finland)	2,253	87.6	na	na
50	American Cyanamid (U.S.)	2,241	46.4	236	10.5

Note: Foreign currencies converted to U.S. dollars using average exchange rates for 1989. **a** Operating profits as a percentage of sales. **b** Contains substantial nonchemical sales. **c** Fiscal year ends Sept. 30. **d** Fiscal year ends March 31. **e** Net income. **na** = not available.

Presidential Young Investigator Awards Program under Review

Prestigious NSF program succeeds at advancing careers of researchers who win, but criticism of selection process may lead to changes

Pamela S. Zurer, C&EN Washington

An assistant professor aiming for the fast track can hardly do better than win one of the National Science Foundation's Presidential Young Investigator (PYI) awards. The guaranteed research funding—a minimum of $25,000 a year for five years from NSF, with the possibility of up to $100,000 annually if the PYI successfully hustles matching funds from industry—can fuel a fledgling laboratory.

Just the prestige of capturing the highly competitive honor can jump start a young scientist's career. And the award certificate signed by the President enhances any office wall.

But critics both within NSF and in the academic community are wondering if the PYI program is really the best use of the agency's funds in an era of tight budgets. The process of selecting the winners seems to give an advantage to young investigators with the right pedigree. And once chosen, winners of PYI awards have definite advantages over their equally talented peers who lost out.

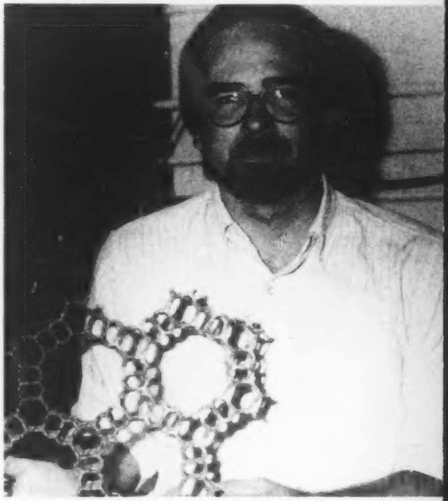
"There's no way I would be where I am without a PYI," says Peter G. Schultz, professor of chemistry at the University of California, Berkeley. He won the award in 1985, just as he was setting up his first independent lab as an assistant professor.

"Without the PYI I would have been in very bad financial straits," Schultz says. "My first two proposals to major funding agencies weren't funded—they thought my work was just too speculative. The PYI money allowed me to do science that was risky and novel and see whether it would work. The payoff has been incredible."

That payoff includes Schultz's innovative research on catalytic antibodies, which was cited by NSF when in 1988 he won the agency's Alan T. Waterman Award, given annually to an outstanding young scientist in the U.S.

Two other PYIs also have won the Waterman award. Chemist Jacqueline K. Barton, who was one of the first class of PYI awardees in 1984 and is now a professor at California Institute of Technology, won the Waterman in 1985. And Mark E. Davis, professor of chemical engineering at Virginia Polytechnic Institute & State University and a 1985 PYI, earlier this year became the first engineer to win a Waterman.

Those three superstars might well have shot to the top without the boost of a PYI award. But PYIs' careers in general move faster than those of their peers, according to a recent major evaluation of the PYI program commissioned by NSF. The as-yet-unreleased study, a copy of which was obtained by C&EN, was submitted to NSF by the research firm of Westat Inc. of Rockville, Md., in March. It shows PYIs are more likely to be full professors than either finalists who were nominated for PYIs but didn't make the final cut, or other NSF grantees at a comparable career stage.



Competition for PYI awards is tough

Fiscal year	Nominations	Awards	Success rate
1984	1549	200	12.9%
1985	1089	200	18.4
1986	886	100	11.3
1987	1122	200	17.8
1988	1806	148	8.2
1989	1657	197	11.9
1990	1591	211	13.3
TOTAL	**9700**	**1256**	**12.9%**

Note: Figures are for all NSF. Budget cutbacks limited the number of awards made in 1986 and 1988. **Source:** National Science Foundation

Those hard data confirm the opinions of most of the PYIs in the study, who reported that they perceived their careers as progressing faster than their contemporaries. Furthermore, a substantial number of the young academics who were not PYIs commented that they thought PYIs had real advantages, because the PYI funds allowed them to concentrate on research rather than constantly writing proposals.

"I've been clearly at a disadvantage," says one recently tenured young professor who never won a PYI. "I've had to spend infinitely more time hustling money. A PYI award would have made a big dif-

C&EN staff photo

C&EN staff photo

PYI award winners Davis (left), Barton (top), and Schultz went on to win the Waterman award

ference early on in terms of allowing me to focus on the lab."

Although the Westat study makes clear that many young investigators have flourished as PYIs, it also demonstrates that the PYI program has failed to meet the goals set for it when it was proposed in 1982 by then Presidential Science Adviser George A. Keyworth II. Alarmed that the brightest young engineers and scientists were deserting academia for better paying industrial jobs, Keyworth sought a way to make academic teaching and research careers more attractive.

But the study shows the PYI program has virtually no effect on attracting and retaining outstanding Ph.D.s in academia. The evaluation found that PYIs are firmly committed to their academic careers—but no more so than the control groups that did not receive the encouragement of the award.

"I don't think anybody has made a decision to go to academia rather than industry on the basis of the PYI program," says Barton, who a few years ago served on an oversight review panel for the program. "That decision gets made long before."

From the Westat report, it's evident that the PYI program's main effect has been to bolster the careers of the select few lucky enough to win the awards and to enhance the prestige of the universities where the PYIs work—findings likely to reinforce the discontent with the program that exists both within NSF and academia. Much of the criticism centers on the way young researchers are chosen to be PYIs—a process in which who you know and where you went to school seems to play as large a part as what you've accomplished.

Because the program is targeted at assistant professors just beginning their independent careers, the selection process relies heavily on letters of recommendation. Candidates are nominated by their department heads at the schools where they have tenure-track positions. No formal research proposal is required, only a one-page outline of research interests.

"The system seems designed to award certain types of background," says Thatcher W. Root, a PYI who is an assistant professor of chemical engineering at the University of Wisconsin, Madison. "People who made all the right career moves are more likely to win a PYI."

"The selection process is in fact a beauty contest," says Henry A. McGee, director of NSF's engineering directorate's chemical and thermal systems division. "It's very clear that approximately half of all PYIs have Ph.D. degrees from a handful—six or seven—of universities. If you have glowing letters of recommendations from persons whose names review panelists would likely recognize, then that's going to work positively in the selection of that particular candidate."

(According to the Westat report, the universities that produced almost half of the first two classes of PYIs are UC Berkeley, Stanford, Caltech, Harvard, Illinois, Massachusetts Institute of Technology, and Princeton. C&EN's own informal analysis finds that a plethora of chemistry PYIs received their Ph.D.s at UC Berkeley, Stanford, Caltech, or Harvard.)

Few critics would argue that the outstanding young scientists and engineers who win PYI awards don't deserve the honor. Rather, they point to the number of equally deserving individuals who feel shut out of an unfair process. NSF's chemistry division, for example, gets about 100 nominations each year but can award only about 15 PYIs.

"There are a tremendous number of talented young people in chemistry," says Paul G. Gassman, professor of chemistry at the University of Minnesota. "But many young investigators view the PYI program as one in which your opportunities are negligible unless you have had or have an association with one of a relatively small number of universities in the U.S." Gassman, who currently is president of the American Chemical Society, stresses his opinions are personal and not an official ACS position.

"I strongly feel that the PYI program is money misspent," Gassman says. He would prefer to see the funds directed toward researchers who have recently received tenure, instead of to beginners who haven't yet established records of independent research and so can be judged only by recommendations.

PYI awards now consume about 4% of chemistry division's budget

Fiscal year	PYI funding, $ millions	Chemistry division budget, $ millions	New PYI chemistry awards	Continuing PYI chemistry awards
1984	$0.4	$79.3	13	—
1985	1.3	87.6	12	13
1986	1.9	85.8	8	25
1987	2.4	93.8	12	33
1988	2.9	94.0	15	45
1989	3.4	96.7	15	47
1990	3.9	99.7	15	50

Source: National Science Foundation

Criticisms like Gassman's are heard all over the country and at NSF itself. Partly in response to such complaints, in mid-October the agency convened a task force to review the PYI program as well as other NSF activities for young investigators. Mary E. Clutter, assistant director for biological, behavioral, and social sciences, was asked by acting director Frederick M. Bernthal to put the group together.

"We will be looking at just what the impact of the PYI program has been," says Clutter. The task force members will consider earlier reports of PYI oversight committees, composed of visiting scientists, as well as the Westat report. Clutter expects the task force's report, scheduled to be finished by December, will list options and recommendations for the future of the program.

"Some critics say there are too many PYIs," Clutter says. "Is the program still appropriate? Is this what we want to do with the taxpayers' money? Anytime we enter into an era of tight budgets, anything that takes a big toll of what individual programs can support will be looked at critically."

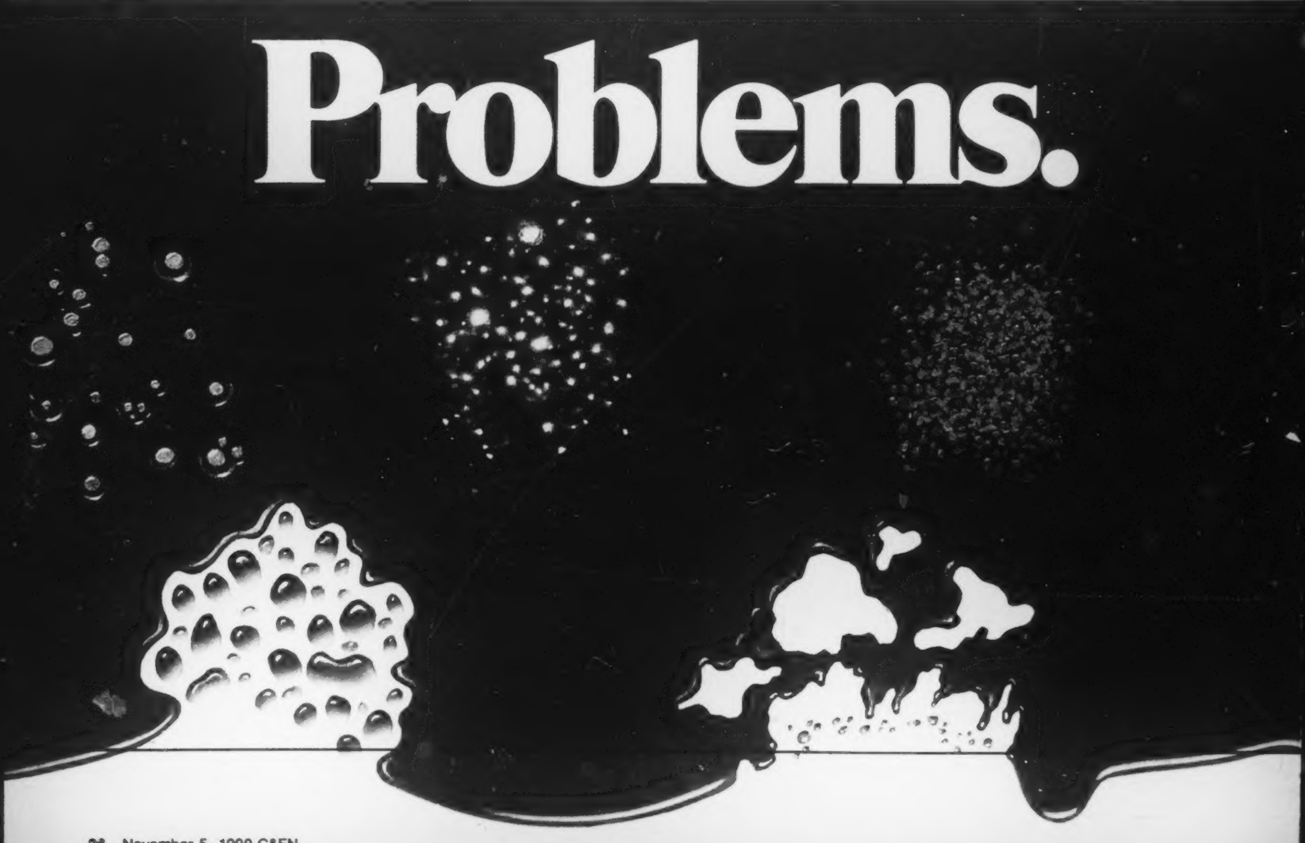
The money NSF is spending on the PYI program, while not huge, is not insubstantial given the current federal funding squeeze. The agency has spent about $209 million in the first seven years of the program, according to Terence L. Porter, director of NSF's division of research career development and chairman of an intra-agency steering committee that coordinates the PYI program.

The catch is that PYI funds come out of the same pots of money as do standard NSF investigator-initiated grants. NSF's chemistry division, for example, does not expect to increase its PYI awards above the 15 per year it has awarded for the past several years because the money comes out of the division's general pool of grant funds, according to division director Kenneth G. Hancock. Chemistry is now spending about $4 million a year to support its PYIs—approximately 4% of the division's $100 million budget.

"We spend about 81% of our budget on single-investigator awards," Hancock says, "and PYI awards are single-investigator awards. That $4 million for PYIs can't be spent on someone else. It's a trade-off pitting PYIs against other new investigators."

Hancock also points out that the five-year term of PYI awards—one of the most attractive features to those that win them—runs counter to the NSF norm of three years. "If all our grants ran for five years, only 20% of the budget each year would be available for anything new," he says. "In a three-year cycle, we have more flexibility. It's important not to be overcommitted, especially in lean years."

PYI funds take an even bigger chunk—more than 10%—out of the budget of NSF's engineering direc-



torate. Engineers receive the lion's share of PYI awards—about 80 of the roughly 200 that have been awarded most years. That situation's historical roots lie in Keyworth's particular concern over a shortfall of engineering educators.

"There's a feeling that perhaps there are too many engineering PYIs," McGee says. "Support for 80 new PYIs a year must come out of the engineering directorate's budget of only $200 million. Contrast that to chemistry's 15 PYIs a year out of a $100 million division budget."

Other complaints about the PYI awards involve the way the honor is used—or perhaps abused—at certain universities. Some schools are said to nominate everybody on their staff who is eligible, helping the candidates solicit very strong letters of recommendation.

That strategy makes good sense given the way PYIs are chosen, McGee says. "A chairman needs to nominate all possible candidates," he says. "To not do so implies the selection process is superlogical. It's not; it's a beauty contest."

Tenure decisions sometimes hang on whether the candidate is a PYI. One prestigious U.S. chemistry department is said to refuse tenure to its young faculty who have not won PYI awards, as if there were something substandard about them. C&EN was not able to confirm the rumor.

"The phrase we sometimes hear is 'PYI or die,' " McGee says. "To the extent that it happens it's absolutely dreadful, particularly in view of the PYI selection process being so unstructured."

On the other side of the coin, beginning researchers who depended on PYI support to get their research efforts going find that that support is sometimes held against them. University administrators expect to see evidence that young faculty can bring in major federal grant money—and because PYI funds are awarded without benefit of a research proposal, they may be discounted in tenure decisions.

Such was the case with PYI Robin L. Garrell, an assistant professor of chemistry at the University of Pittsburgh. "The PYI funds allowed me to support a research group," Garrell says. "But in the eyes of the leadership of the department, that money didn't count because it was not from a peer-reviewed grant." Garrell, denied tenure at Pittsburgh, has since won major grants from NIH and NSF.

Garrell also found that obtaining matching PYI research funds from industry was more difficult than she had anticipated. From the outset of the program, one of its main goals was to improve ties between industry and academia. Therefore, NSF will match any industrial funding PYIs can obtain on a dollar-for-dollar basis up to $37,500 per year.

Across all disciplines, PYIs have succeeded in raising about 75 to 80%

Solutions.

3M

of the maximum $37,500 available for matching, according to NSF's Porter. Chemists and chemical engineers have done somewhat better than average in obtaining industrial funds, in no small part because of the efforts of the Council for Chemical Research.

CCR is a nonprofit group composed of the heads of university chemistry and chemical engineering departments and leaders of research divisions at companies heavily dependent on chemistry. It was founded in 1979 to promote cooperative activities between universities and industry.

Since the inception of the PYI program, CCR members have provided a significant portion (about 20%) of the industrial funds chemistry PYIs have obtained. The organization itself has actively sought to spread the word about PYIs by distributing information to its members about each new group of awardees. For several years, chemistry and chemical engineering PYIs were invited to present their work at CCR's annual meeting, although that interaction proved to be less useful than hoped.

"We try to stir up interest in the PYI program among our industrial members," says Theodore E. Tabor, manager of cooperative research at Dow Chemical and Dow's alternate representative to CCR. "The PYI program for us is a screening mechanism that allows us to say maybe these are young hotshots we should take a chance on. And the PYIs we fund find our support really helps them because they can get matching funds."

C&EN staff photo

C&EN staff photo

Hancock (above) and McGee: research proposals may be required

Dow has supported a number of chemistry PYIs at $37,500 a year for the full five years of the award. In general, however, obtaining industrial research money has not been easy for PYIs, especially in disciplines such as mathematics or astronomy. Indeed, the Westat report found PYIs had no greater contact with industry than their peers by several different measures.

Soon after the program started NSF eased its requirements for matching funds, making monies from nonprofit organizations and the value of gifts of research equipment eligible. For example, Joshua L. Goodman, assistant professor of chemistry at the University of Rochester, has used grants he received from the Petroleum Research Fund and a discount on a laser purchase to qualify for matching funds during his first year as a PYI. "I'm not sure how easy it will be to get industrial support," he says, indicating he hasn't got much response to his efforts so far.

"I don't think the PYI program turned out to be the golden entry card to industry that NSF thought it would be," says Wisconsin's Root. He has obtained the bulk of his industrial funding from AT&T Bell Labs, where he had a postdoctoral stint before moving to Wisconsin. "Cold calls are very difficult and not likely to be successful. If you have personal contacts you have a much better chance," Root says.

Despite its problems, the PYI program has no lack of supporters. Kendall N. Houk, chemistry professor at UCLA, who recently served two years as director of NSF's chemistry division, thinks the PYI program should be expanded, if anything. "The best part is we identify some terrific people at an early age and give them money to get a good start," he says.

Houk does not view the lack of a research proposal in the PYI selection process as a problem. "There's no doubt the people who are picked are leaders in the field," he says. "Why make them write and rewrite proposals?"

Berkeley's Schultz agrees. "The good the program does far, far outweighs any injustices that might be inherent in the system," he says.

Continued on page 49

Goodman (left) and Garrell: matching funds not so easy to come by

Continued from page 36

in being able to discuss science policy face-to-face with Congressmen.

CSSP develops action plans and position statements, which are proposed, debated, and voted upon within the two-day meeting. CSSP members and a small permanent staff bring concerns and issues to one of three council standing committees: Government & Public Affairs, Mathematics & Science Education, and Ethics in Science. Proposed resolutions and brief background information subsequently are brought to the full council. A number of approaches are used to ensure the effectiveness of the CSSP position statements: letters to specific, interested individuals; resolutions sent to key groups or organizations; personal approaches by CSSP members to their respective elected representatives and other policymakers; and, by invitation, critical review of and testimony on important pieces of legislation or regulation. Additionally, all of the adopted policies and other activities and business of the council are routinely reported in the quarterly newsletter, *CSSP News.*

When pressing matters emerge between the regular meetings of the full council, they are typically considered by the CSSP executive board, made up of the chairman, chairman-elect, secretary, treasurer, and three members-at-large.

Recent CSSP policy statements have addressed issues such as research funding, science and mathematics education, animal research, National Institutes of Health guidelines for conflicts of interest, and the role of scientific societies in advancing the public understanding of science.

Each year CSSP confers its Award for Support of Science to honor an individual who merits recognition for dedicated support of science, including support of science and mathematics education, support of free scientific communication, support of basic research, and support of public understanding of science.

Periodically, the council engages in special events or activities conducive to the advancement of science and mathematics. A recent example is the May 1990 conference in Racine, Wis., entitled "Bridging the Communications Gap: A Wingspread Workshop to Strengthen the Relationships between Scientists and Journalists."

This conference, supported by the Johnson Foundation and the National Science Foundation, brought together 21 senior science journalists and 20 society presidents to reach a better appreciation of the standards, conventions, motivations, and constraints associated with each of the two professions and—based on these understandings—to develop specific methods for facilitating mutually productive interactions between the scientific community and the media with the intended effect of improving the timely flow of scientific information to the public.

In summary, it is apparent that—more than ever before—the Council of Scientific Society Presidents is a useful and valued voice in support of the broad spectrum of the sciences and mathematics, and their respective professions, in the service of society and the environment. Within this enterprise, chemistry benefits as the overall prospects for science improves, and chemists benefit as the overall prospects for civilization and the environment improve. It is a particular pleasure for me to emphasize and applaud the fact that the American Chemical Society has been a sustaining supporter of CSSP beginning with its creation in 1973. In my opinion, the results have been such that the generous support of ACS and the other supporting societies is amply justified.

For further information on CSSP or for copies of any of the issued policy statements, contact Eric Leber, CSSP Executive Director, at (202) 872-4452. □

Government

Continued from page 28

"It's unfortunate the program can't help everybody. Anytime you have to make choices among people, some good people will be left out."

Many PYIs agree that the program's particular strength is the freedom it allows to pursue unconventional ideas. "The program was exceedingly helpful to me because I was not held to a rigorous research plan," says Virginia Tech's Davis, who will be moving next year to Caltech. "We used the funds to explore very high-risk projects that would have been quite difficult to fund through normal channels."

Nevertheless, it's likely that the PYI program will soon be reshaped. A recent NSF report on the agency's peer review process suggested that the PYI program be "mainstreamed." That is, PYI award winners would be picked from the pool of peer-reviewed grant proposals. The other special characteristics of the PYI award, such as the provision for matching funds and Presidential recognition, would remain in place so it would retain its distinction.

"That suggestion would remove the taint that's on the PYI program," Garrell says. "The awards would be peer reviewed but with some honor added."

That recommendation fits well with thinking going on within the chemistry division at NSF. "In the chemistry division we've begun to explore with our advisory committee and review panels whether we should continue in the same fashion," Hancock says. "Our evolving position is that we might advocate replacing the existing PYI program with something we'd call a 'starter grant.' It would be a sheltered program for young investigators who would write a proposal that would be peer reviewed."

NSF's McGee predicts that a change to requiring research proposals for PYIs will likely be recommended by the task force now reviewing the program. He also thinks the length of the award may be shortened from five years to something less.

"The key word really should be nurturing," McGee says. "I've served on PYI selection panels and all the applicants are outstanding. . . . Nurturing is what we should be providing these young researchers, not Darwinian blood and guts competition." □

Third-quarter chemical company earnings plunge
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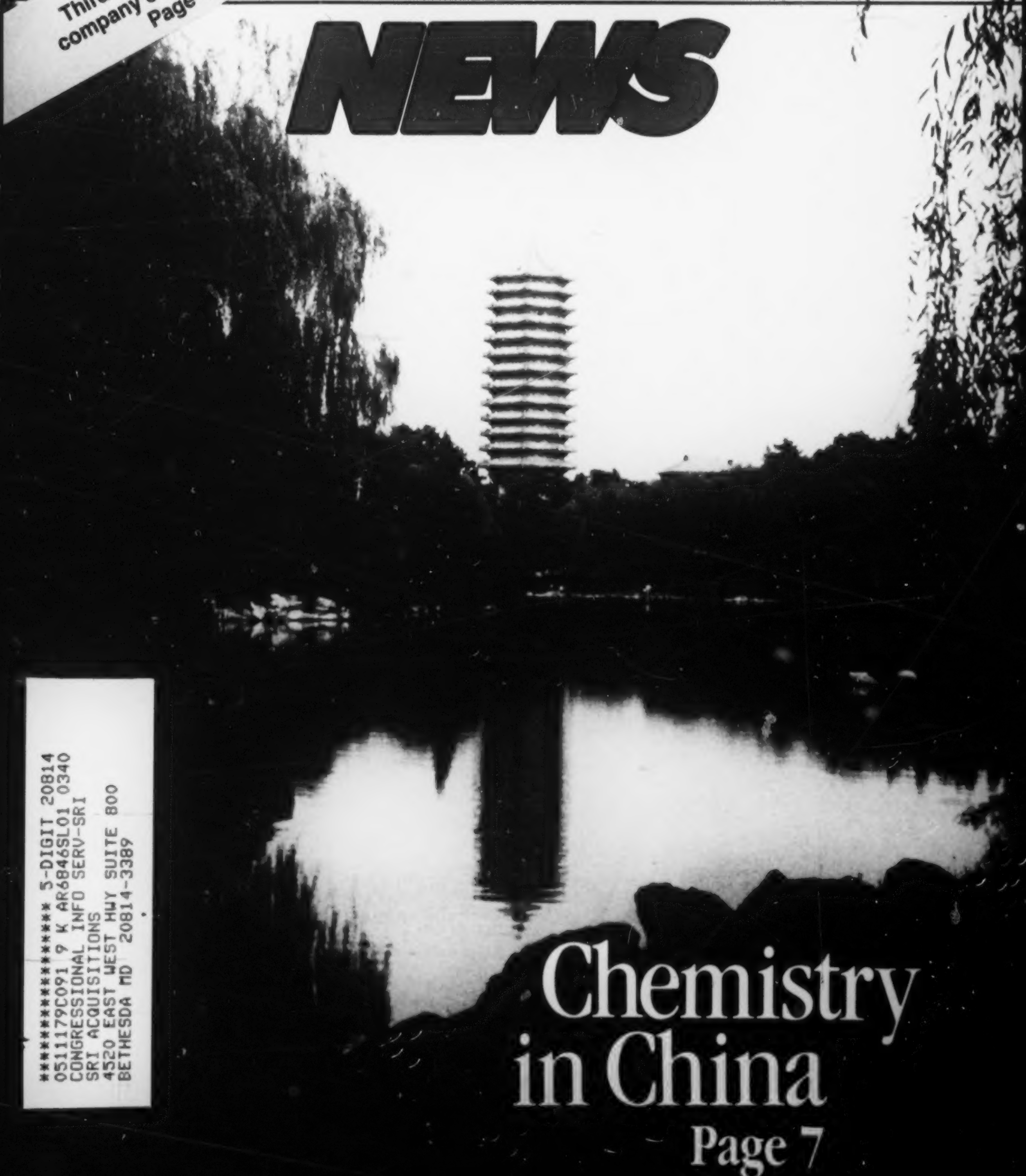
NOVEMBER 12, 1990

CHEMICAL & ENGINEERING NEWS



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Chemistry in China

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Volume 68, Number 46
CENEAR 68 (46) 1-56
ISSN 0009-2347

CHEMICAL & ENGINEERING NEWS

NOVEMBER 12, 1990

News of the Week

- **Elections returned most Congressional incumbents who hold key positions in science and technology, and brought stinging defeats to several state environmental referenda.** **Page 4**
- **FAA introduces improved explosive-detection system for baggage screening at airports that combines thermal neutron analysis and x-ray screening.** **Page 5**
- **Fast-food giant McDonald's will stop using polystyrene foam packaging, including the familiar clamshell-like burger container, at all its restaurants.** **Page 5**
- **Scientists insert foreign DNA into chloroplasts of tobacco plants—the first such achievement in multicelled plants.** **Page 6**
- **Japanese white paper on science and technology calls for efforts to improve the quality of life for Japan's, and the world's, citizens.** **Page 6**

Cover: Water tower in the form of a pagoda near Nameless Lake at the University of Peking. Photo by C&EN's Joseph Haggin

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Business

Chemical company earnings continued their slide into the third quarter, marking the fifth quarter in a row that results fell; chemical marketing research conference in Budapest looks at prospects in Eastern Europe; France promotes huge chemical complex near Marseilles. **Page 14**

Government

1990 Clean Air Bill revision allows EPA to halt air pollutants at source, a move likely to be costly to chemical industry. **Page 23**

Science Policy

Bush Administration will face some tough decisions as it develops a full-fledged national technology policy. **Page 25**

Education

Careers in materials science were focus of recent conference for undergraduates held at University of Wisconsin, Madison. **Page 27**

Science/Technology

Two bacterial enzymes that catalyze mechanistically distinct reactions are structurally homologous, suggesting possible evolutionary link; Rochester, N.Y., scientists build scanning tunneling microscopes for loan to 15 private colleges and universities. **Page 30**

Awards

ACS award winners: Poulter, Reiss, Roth, Small, Solomon, Stork, Vandenberg, Weinberg, Willson, and Zare. **Page 37**

News Focus

Chinese scientific and technical progress, crucial to country's becoming a competitive industrialized nation, is showing need for professionals to have closer association with counterparts outside China. Page 7

Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036
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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director
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Subscription Rates 1990. Printed editions: nonmembers U.S. 1 yr. $60, 2 yr. $108, outside U.S. 1 yr. $93, 2 yr. $174. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $9.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Energy-efficient gas turbines

I read with great interest the article on energy research by Janice Long (C&EN, Sept. 10, page 16). When the topic is fuel-efficient automobiles, various proposals are discussed, all involving improvements in the internal combustion engine. Others have proposed the Stirling external combustion engine, which can use fuels other than gasoline.

Never does anyone mention gas turbines, which operate at higher temperatures leading to much higher Carnot efficiency. They can operate on many fuels, including hydrogen. The drawback is that maximum efficiency requires top speed, precluding speed control by variable fuel feed. The solution is turboelectric. The turbine drives a generator whose output is fed to one or more electric motors driving the wheels. There is a variety of possible ways to implement such systems. The U.S. Navy built several torpedo boats in World War II based on this system.

Ephraim Banks
Professor Emeritus
Polytechnic University
New York City

Celluloid's commercial success

Stu Borman's well-written article, "Conference Offers Insights on Challenges Facing Science Historians" (C&EN, Aug. 6, page 23) offers a fascinating summary of the many opportunities available to scientists in general, and chemists in particular, especially in forming alliances with teachers and historians. The conference appears to have covered a wide range of historical and scientific issues.

One comment in the article prompts me to point out an important fact that was omitted either from the reporting or from the conference. On page 27, Borman notes that celluloid was invented in 1870 by John Wesley Hyatt. However, this material owes its real commercial success to the years of developmental effort spent by Swiss-born chemists Camille and Henry Dreyfus. Between 1908 and 1911, the Dreyfus brothers carried out more than 20,000 experiments to develop a production process, exploring topics such as the nature and proportion of catalyst, quantities of acetylating agents and diluents, times and temperatures of acetylation, and the nature of the raw cellulose. The first to realize the effect of cellulose acetate's acetyl content on the material's properties, they also showed that viscosity, high tensile strength, and elasticity are complementary, and found how to avoid cellulose degradation, long before the polymeric nature of cellulose was discovered many years later. The first to discover methods of converting cellulose acetate into workable and dyable fibers, they founded Celanese Corp. and paved the way for development of the modern synthetic fibers industry. For their efforts, Henry Dreyfus received the Perkin Medal in 1938, which, characteristically, he accepted in his brother's name as well.

Robert L. Lichter
Executive Director
Camille & Henry Dreyfus Foundation
New York City

Xenon as an anesthetic

In one of your Science/Technology Concentrates (C&EN, July 2, page 20) it was announced that xenon has been found to be a good anesthetic. Xenon is that, and it is good to see that it has been put through some clinical trials. However, this is not a new finding; it has been known for decades. In fact, Linus Pauling, partly on the basis of his crystallographic work on xenon hydrates, published "A Molecular Theory of General Anesthesia" [*Science*, **134**, 15 (1961)].

Karl Seff
Professor of Chemistry
University of Hawaii, Manoa

Solving national problems

I read with concern "Changes in Immigration Law Eyed To Avert Shortage of U.S. Scientists" (C&EN, Aug. 20, page 19). Here is another sad example of how we solve our national problems.

First, we lack the will to develop any national energy policy that reduces our reliance on oil. Then, because of our gigantic (and growing) appetite for this scarce U.S. resource, we require the import of foreign oil for 55% of our consumption. Then we send American military forces to Saudi Arabia so we can continue the import folly.

Second, we lack the will to be fiscally responsible. Then, to float the gigantic (and growing) national debt, we must depend on foreign dollars. Then we become the world's largest debtor nation, and captive to an endless list of foreign country trade and financial policies, many of which are basically inimical to the U.S. national interest.

And now third, we lack the will to properly construct and operate our edu-

Chemical Earnings Nosedive Continues in Third Quarter

William J. Storck,
C&EN Northeast News Bureau

Earnings in the chemical industry averaged a double-digit decline in the third quarter compared with a year ago. Earnings for oil companies, however, were up slightly at 2% and were essentially flat for diversified manufacturers. And profits at drug companies were up strongly at 18% over the year-earlier quarter.

Total earnings at the 30 chemical companies regularly surveyed by C&EN declined 25%, continuing the trend that started in the middle of last year. This was the fifth quarter in a row that results fell and it is the fourth straight quarter that the earnings contraction has been greater than 20%.

However, the third quarter was full of inconsistencies. While combined earnings at the 30 companies dropped, sales for the group averaged a rise of 10%, the best year-to-year sales growth performance since the first quarter of 1989.

And, in spite of the much talked about chemical slowdown, only 12 of the 30 companies registered earnings declines. This is the same number that showed declines in the second quarter. Thus, it seems that even at this late date, the slowdown is not being widely felt in the chemical industry, and is not spreading very fast throughout the companies.

What is being felt, however, is the crisis in the Middle East. Many of the companies that had large earnings declines in the third quarter are those that are heavily dependent on feedstocks, the prices of which are closely related to oil's. Among these firms with well above average declines are the three largest on the list, Dow Chemical, Union Carbide,

Chemical industry leaders for third quarter . . .

Sales				Earnings[a]			Profitability		
Rank 1990		$ Millions	Rank 1989		$ Millions	Rank 1989		Earnings as % of sales	Rank 1989
1	Dow Chemical	$4,919.0	1	Dow Chemical	$284.0	1	International Flavors	16.2%	2
2	Union Carbide	2,203.0	2	Union Carbide	91.0	2	Great Lakes Chemical	13.2	5
3	Monsanto	2,140.0	3	Monsanto	74.0	3	Loctite	12.7	6
4	W. R. Grace	1,671.6	4	Air Products	63.1	6	Betz Laboratories	11.5	8
5	American Cyanamid	1,056.3	5	Ethyl	56.2	5	Nalco Chemical	10.9	7
6	Air Products	816.3	7	Arco Chemical	56.0	4	Lubrizol	10.5	12
7	Hercules	812.0	6	American Cyanamid	52.0	7	Georgia Gulf	10.0	1
8	Rohm & Haas	683.6	9	B. F. Goodrich	50.6	9	Ethyl	9.0	10
9	Arco Chemical	681.0	8	Rohm & Haas	45.9	12	Arco Chemical	8.2	3
10	Olin	656.0	12	W. R. Grace	45.2	10	B. F. Goodrich	8.0	16

. . . and for the first nine months of 1990

Sales				Earnings[a]			Profitability		
Rank 1990		$ Millions	Rank 1989		$ Millions	Rank 1989		Earnings as % of sales	Rank 1989
1	Dow Chemical	$14,626.0	1	Dow Chemical	$1110.0	1	International Flavors	17.2%	2
2	Monsanto	6,793.0	2	Monsanto	515.0	2	Great Lakes Chemical	13.4	3
3	Union Carbide	6,511.0	3	Union Carbide	301.0	3	Loctite	12.4	7
4	W. R. Grace	4,807.5	4	American Cyanamid	257.3	5	Arco Chemical	11.6	4
5	American Cyanamid	3,437.1	5	Arco Chemical	240.0	4	Betz Laboratories	11.1	9
6	Hercules	2,379.0	6	Air Products	174.2	7	Georgia Gulf	10.8	1
7	Air Products	±2,242.2	9	Rohm & Haas	170.0	8	Nalco Chemical	10.8	8
8	Rohm & Haas	2,146.5	8	Ethyl	165.8	6	Lubrizol	9.4	13
9	Arco Chemical	2,071.0	7	W. R. Grace	129.1	12	Ethyl	9.0	10
10	Olin	1,952.0	10	International Flavors	127.8	11	Vista Chemical	8.1	6

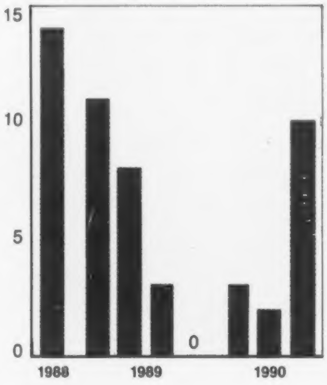
Note: Based on 30 chemical companies listed on page 16. a After taxes.

Chemical industry 1990 third-quarter results

- **Sales were up 10%**
- **Earnings fell 25%**
- **Profit margins at 5.4%**
- **Production rose 2.1%**
- **Prices edged up 0.9%**

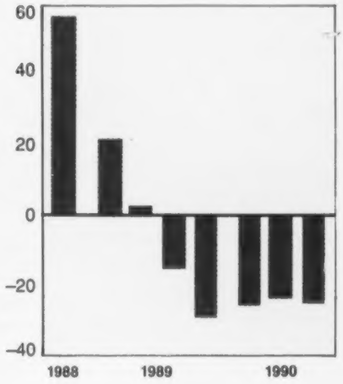
Sales

% change from year-earlier quarter



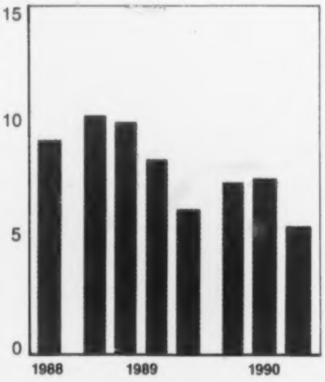
Earnings

% change from year-earlier quarter



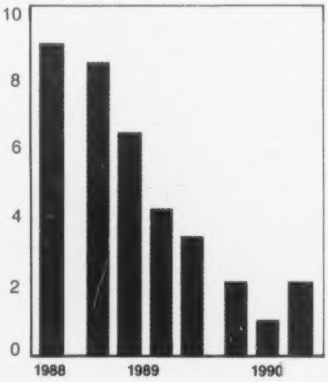
Profit margins

After-tax earnings as % of sales



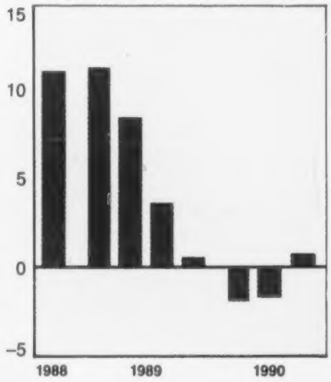
Production

% change from year-earlier quarter



Prices

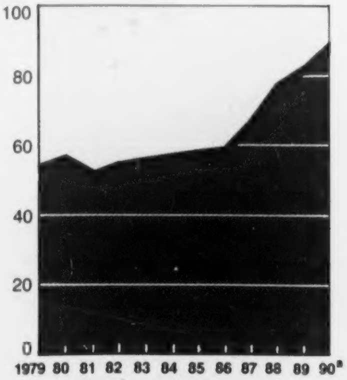
% change from year-earlier quarter



Sales in 1990 will rise about 7% while earnings will be down 26%, pushing down profit margins to about 6%

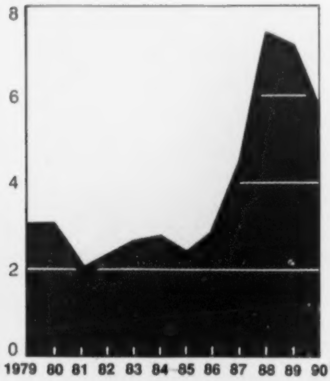
Annual sales

$ Billions



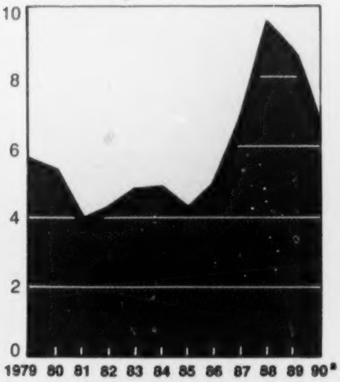
Annual earnings

$ Billions



Annual profit margins

After-tax earnings as % of sales



Note: All sales, earnings, and profit margin data are based on combined results of 30 companies listed on page 16. a C&EN estimates.

Many chemical companies register big profitability declines in third quarter

	THIRD-QUARTER 1990						NINE-MONTHS 1990			
	Sales	Earnings[a]	Change from 1989		Profit margin[b]		Sales	Earnings[a]	Change from 1989	
	($ millions)		Sales	Earnings	1990	1989	($ millions)		Sales	Earnings
Air Products	$ 816.3	$ 63.1	22%	24%	7.7%	7.6%	$ 2,242.2	$ 174.2	12%	12%
American Cyanamid	1,056.3	52.0	9	2	4.9	5.3	3,437.1	257.3	7	14
Arco Chemical	681.0	56.0	8	–40	8.2	14.9	2,071.0	240.0	1	–27
Betz Laboratories	153.4	17.6	15	17	11.5	11.3	444.4	49.4	14	17
Cabot	399.9	10.1	–10	def	2.5	def	1,267.0	41.4	–13	31
Chemed	155.1	5.1	1	–36	3.3	5.1	450.4	14.6	1	–28
Crompton & Knowles	96.3	7.0	10	20	7.3	6.6	289.1	22.7	7	23
Dow Chemical	4,919.0	284.0	16	–52	5.8	13.9	14,626.0	1110.0	10	–46
Ethyl	624.2	56.2	2	3	9.0	8.9	1,840.0	165.8	3	6
First Mississippi	134.9	4.3	32	372	3.2	0.9	398.4	6.4	11	–6
H. B. Fuller	203.1	6.4	7	68	3.2	2.0	589.2	14.0	5	32
Georgia Gulf	232.7	23.2	–7	–50	10.0	18.3	703.1	76.3	–18	–49
B. F. Goodrich	634.5	50.6	6	29	8.0	6.5	1,856.8	101.7	1	–29
W. R. Grace	1,671.6	45.2	12	23	2.7	2.5	4,807.5	129.1	9	16
Great Lakes Chemical	268.1	35.4	17	12	13.2	13.8	776.9	104.3	37	14
Hercules	812.0	29.5	3	–3	3.6	3.9	2,379.0	99.8	3	–8
Imcera Group	375.7	18.0	19	140	4.8	2.4	1,132.2	64.5	35	–13
International Flavors	248.1	40.3	14	18	16.2	15.8	743.5	127.8	9	12
Loctite	138.9	17.6	21	22	12.7	12.6	412.0	51.0	17	14
Lubrizol	364.7	38.4	34	79	10.5	7.8	1,075.8	100.6	14	29
Monsanto	2,140.0	74.0	4	–41	3.5	6.1	6,793.0	515.0	2	–13
Morton International	451.9	33.7	27	30	7.5	7.3	1,328.1	103.3	22	23
Nalco Chemical	300.3	32.7	11	1	10.9	12.0	886.8	95.5	13	9
Olin	656.0	15.0	13	–38	2.3	4.1	1,952.0	76.0	2	–18
Petrolite	73.5	2.8	2	–56	3.7	8.7	218.2	10.0	1	16
Quantum Chemical	621.9	–1.4	12	def	def	3.6	1,890.7	11.5	–8	–92
Rohm & Haas	683.6	45.9	10	41	6.7	5.2	2,46.5	170.0	5	10
Union Carbide	2,203.0	91.0	3	–35	4.1	6.5	6,511.0	301.0	–2	–43
Vista Chemical	182.1	7.8	–3	–63	4.3	11.3	548.8	44.5	–7	–50
Witco	419.3	19.6	6	–4	4.7	5.2	1,217.8	57.4	1	–10
TOTAL	**$21,717.6**	**$1181.1**	**10%**	**–25%**	**5.4%**	**8.0%**	**$65,034.5**	**$4335.2**	**5%**	**–25%**

a After-tax earnings from continuing operations, excluding significant nonrecurring and extraordinary items. b After-tax earnings as a percentage of sales. def=deficit.

and Monsanto, as well as a number of companies with close ties to petrochemicals, such as Quantum Chemical, Arco Chemical, Vista Chemical, and Georgia Gulf.

Again, adding to the complexities, a few of these companies had very respectable increases in sales. This indicates that, although the firms may be getting price hikes, these increases are not keeping up with the rise in the price of oil and other basic feedstocks, creating a considerable profit squeeze.

The increased sales may also mirror the weakness of the dollar against foreign currencies. Thus, though companies can sell increased quantities of product overseas, the dollar value of each pound of product goes down as the foreign currency in relation to the dollar strengthens.

Although third-quarter results followed most of the chemical economic fundamentals, there were some anomalies here as well. Normally in any given period the sum of the price increase and the production increase will approximate the increase in sales. According to government data, prices rose about 1% in the third quarter over the same period last year. And production of chemicals and allied products was up about 2% from the year-earlier level. The 3% sum, however, comes nowhere near the 10% sales increase recorded by the 30 companies. Since the increased sales volume had to come from somewhere other than production, it could only come from inventories. And this indeed seems to be the case.

Though inventory data are available from the government only through August, the data for that month show that producer stocks of

NINE-MONTHS 1990		12-MONTH RUNNING DATA			
Profit margin[b]		Change from 1989		Profit margin[b]	
1990	1989	Sales	Earnings	1990	1989
7.8%	7.8%	10%	1%	7.7%	8.4%
7.5	7.0	-1	-11	6.2	6.8
11.6	16.0	-4	—23	13.4	16.6
11.1	10.9	14	15	11.0	10.9
3.3	2.2	-13	6	3.6	2.9
3.2	4.6	1	-16	3.4	4.1
7.9	6.8	5	11	6.7	6.4
7.6	15.4	7	-43	8.1	15.3
9.0	8.8	3	0	9.2	9.4
1.6	1.9	17	-40	1.5	2.9
2.4	1.9	5	26	2.5	2.1
10.8	17.5	-17	-35	14.0	17.9
5.5	7.8	-2	-34	5.3	7.9
2.7	2.5	8	21	3.3	2.9
13.4	16.2	42	14	13.5	16.8
4.2	4.7	5	-50	2.1	4.4
5.7	8.8	37	-1	5.0	7.0
17.2	16.8	8	11	16.3	15.9
12.4	12.7	15	13	12.1	12.3
9.4	8.3	12	17	8.6	8.2
7.6	8.8	3	-10	6.5	7.4
7.8	7.7	21	19	7.9	8.0
10.8	11.1	11	11	10.9	11.0
3.9	4.9	1	-6	4.2	4.5
4.6	4.0	1	26	4.6	3.7
0.6	6.7	-12	-88	1.2	9.0
7.9	7.6	5	-3	6.9	7.5
4.6	7.9	-2	-46	4.7	8.5
8.1	15.1	-8	-52	8.1	15.7
4.7	5.3	0	-18	4.2	5.1
6.7%	**9.4%**	**4%**	**-27%**	**6.6%**	**9.4%**

chemicals and allied products were down just 1.2% from the previous August. However, inventories of industrial chemicals, the classification used for the commodities, dropped 9.5% from the same month in 1989. The result was that the inventories-to-shipments ratios for both chemicals and allied products at 1.26 and industrial chemicals at 1.20 were at their lowest levels in years (C&EN, Oct. 22, page 7).

Whatever the factors involved in the third-quarter results, the upshot is that earnings at the 30 chemical companies fell an average 25% to $1.18 billion on a sales increase of 10% to $21.7 billion. As a result of the rapidly declining earnings and increasing sales figures, profitability suffered greatly. Weighted profit margins for the 30-company group fell to 5.4% in the third quarter from 8.0% in the year-earlier quarter, and were down from 7.2% in the second quarter, which is historically stronger than the third.

For the first nine months, combined earnings at the chemical companies were also down 25% to almost $4.34 billion on sales up 5% to $65 billion. As a result, profit margins for the group fell to an average 6.7% for the nine months as opposed to 9.4% for the first three quarters of 1989.

In contrast, earnings at 12 oil companies that are large producers of chemicals rose 2% on average in the third quarter to $3.42 billion on a 22% sales increase to $98.3 billion. Profitability for this group fell to an average 3.5% from 4.2% in the comparable period last year. For 11 diversified companies producing chemicals as well as other products, combined earnings were flat at $1.65 billion on an 11% sales rise to $28.5 billion. This pushed profit margins for the group down to an aggregate 5.8% from 6.4% in the third quarter of 1989.

But once again the recession-resistant pharmaceutical companies were the star performers. At a group of nine drug companies surveyed by C&EN, earnings rose 18% to a total $2.25 billion and sales increased 11% to $14.2 billion. This boosted profitability to an average 15.9% for the group from 15.0% in the same period last year.

The Persian Gulf crisis has had a marked effect on third-quarter results at many of the chemical companies, even though it began just a little less than halfway through the quarter. As previously noted in C&EN, for instance, industrial gas companies such as Air Products and Union Carbide have been forced to place surcharges on prices to cover the increased cost of transportation.

But the biggest damper on earnings has been rising feedstock costs. Dow Chemical, whose earnings plummeted 52% from last year's third quarter, cites soaring oil costs and a faltering economy. The company says that overall prices increased more than 5% from the second quarter, but manufacturing costs also increased as a result of higher feedstock and energy costs. Enrique C. Falla, Dow's financial vice president, says, "By the end of the third quarter, pricing initiatives were in place to offset much of the increases in feedstock costs to date." He also noted that the company's price index likely will increase sharply in the fourth quarter as announced price increases are implemented globally.

Quantum Chemical, which recorded a more than $1 million loss for the quarter, says that profit margins in the propane marketing business declined compared with last year's third quarter primarily because higher propane costs as a result of the Middle East crisis were not fully offset by increased selling prices. Similarly, the company notes, polyethylene margins have narrowed since the second quarter of 1990 because Quantum was unable to pass along increases in the cost of feedstocks.

To see the chilling effect of rising oil prices and energy costs on petrochemicals, one only need look at the performance of the oil companies, which largely produce chemicals based on oil and natural gas. At Exxon, the third largest U.S. chemical producer, earnings from chemical operations fell 57% to $65 million in the quarter. And the company had a $19 million loss on its foreign chemical operations.

Occidental Petroleum's chemical earnings in the third quarter dropped 40% from the year-earlier level to $152 million. The company

Oil, diversified, and pharmaceutical companies show widely differing results in third quarter

	THIRD-QUARTER 1990						NINE-MONTHS 1990					
	Sales	Earnings[a]	Change from 1989		Profit margin[b]		Sales	Earnings[a]	Change from 1989		Profit margin[b]	
	($ millions)		Sales	Earnings	1990	1989	($ millions)		Sales	Earnings	1990	1989
OIL AND GAS COMPANIES												
American Petrofina	$ 1,054.6	$ 26.5	48%	76%	2.5%	2.1%	$ 2,783.5	$ 106.5	22%	1%	3.8%	4.6%
Amoco	7,927.0	530.0	20	58	6.7	5.1	22,434.0	1,375.0	13	7	6.1	6.5
Chevron	10,600.0	323.0	33	−21	3.0	5.1	28,800.0	1,380.0	21	21	4.8	4.8
Exxon	29,107.0	1,075.0	23	0	3.7	4.5	81,818.0	3,455.0	18	3	4.2	4.6
Kerr-McGee	986.2	43.1	32	128	4.4	2.5	2,643.8	100.3	16	14	3.8	3.8
Mobil	16,308.0	379.0	21	−29	2.3	4.0	45,160.0	1,277.0	9	−6	2.8	3.3
Occidental Petroleum	5,350.0	111.0	11	68	2.1	1.4	15,631.0	290.0	4	28	1.9	1.5
Phillips Petroleum	3,430.0	178.0	12	105	5.2	2.8	9,405.0	542.0	0	14	5.8	5.1
Shell Oil	6,205.0	227.0	15	−33	3.7	6.3	17,133.0	590.0	4	−48	3.4	6.9
Sun Co.	3,350.0	25.0	23	−71	0.7	3.1	9,350.0	211.0	13	−22	2.3	3.3
Texaco	10,954.0	381.0	31	25	3.5	3.7	28,831.0	1,062.0	9	20	3.7	3.4
Unocal	3,070.0	121.0	9	51	3.9	2.9	8,429.0	363.0	−1	25	4.3	3.4
TOTAL	$98,341.8	$3,419.6	22%	2%	3.5%	4.2%	$272,418.3	$10,751.8	12%	1%	3.9%	4.4%
DIVERSIFIED MANUFACTURERS												
Allied-Signal	$ 2,961.0	$ 105.0	5%	−13%	3.5%	4.3%	$ 9,200.0	$ 355.0	4%	−9%	3.9%	4.4%
Du Pont	9,933.0	533.0	16	−3	5.4	6.4	28,983.0	1,842.0	9	−8	6.4	7.5
—Eastman Kodak	4,774.0	358.0	5	19	7.5	5.6	13,757.0	941.0	2	15	6.8	6.0
Engelhard	874.6	16.0	49	−9	1.8	3.0	2,284.4	48.9	29	4	2.1	2.6
FMC	941.0	35.4	12	2	3.8	4.2	2,741.7	128.2	6	3	4.7	4.8
Ferro Corp.	281.4	8.0	5	−33	2.8	4.5	843.2	21.2	4	−43	2.5	4.6
3M	3,343.0	336.0	12	9	10.1	10.3	9,741.0	1,013.0	8	6	10.4	10.5
NL Industries[c]	221.0	17.5	−11	−73	7.9	26.4	679.3	83.0	−11	−45	12.2	19.7
PPG Industries	1,470.0	107.1	8	0	7.3	7.8	4,520.0	373.4	5	3	8.3	8.4
Tenneco	3,392.0	91.0	6	1	2.7	2.8	10,630.0	431.0	4	14	4.1	3.7
Vulcan Materials	306.6	42.1	0	−17	13.7	16.4	834.3	100.5	2	−8	12.0	13.4
TOTAL	$28,497.6	$1,649.1	11%	0%	5.8%	6.4%	$ 84,213.9	$ 5,337.1	6%	−1%	6.3%	6.8%
PHARMACEUTICAL COMPANIES												
Abbott Laboratories	$ 1,506.8	$ 220.8	15%	13%	14.7%	15.0%	$ 4,448.6	$ 686.0	13%	13%	15.4%	15.5%
American Home Products	1,743.5	317.6	−2	14	18.2	15.7	5,162.0	902.4	1	13	17.5	15.6
Baxter International[d]	2,020.0	135.0	12	32	6.7	5.6	5,926.0	−138.0	9	def	def	5.6
Bristol-Myers Squibb	2,622.2	495.9	13	21	18.9	17.7	7,563.8	1,322.3	11	20	17.5	16.1
Merck	1,914.3	465.0	17	19	24.3	23.9	5,572.1	1,339.0	16	19	24.0	23.5
Pfizer	1,643.0	243.3	14	12	14.8	15.1	4,620.7	646.4	11	9	14.0	14.2
Shering-Plough	793.0	140.0	7	23	17.6	15.3	2,522.9	434.5	6	21	17.2	15.1
Upjohn	747.1	112.2	13	11	15.0	15.3	2,222.2	342.2	9	12	15.4	14.9
Warner Lambert	1,186.7	124.8	7	17	10.5	9.7	3,441.5	379.5	9	18	11.0	10.2
TOTAL	$14,177.3	$2,254.6	11%	18%	15.9%	15.0%	$ 41,479.7	$ 5,914.3	10%	7%	14.3%	14.6%

a Earnings from operations, excluding significant nonrecurring and extraordinary items. b Earnings from operations as a percentage of sales. c 1989 earnings include gain on disposition of businesses. d 1990 nine-months earnings include major nonrecurring charge. def=deficit.

notes that the reduced earnings resulted from lower selling prices in all major product areas, as well as higher feedstock costs in petrochemicals. And Mobil's chemical earnings fell 30% to $85 million, primarily owing to lower petrochemical margins, although the company registered higher petrochemical sales volumes.

Forecasting the remainder of the year is difficult, considering the problems that arose in the third quarter. Most chemical companies believe that they have programs in place that will at least partially combat the effects of the Middle East crisis. However, in spite of that, it looks like the fourth quarter will be another period of declining earnings for the chemical industry. □

Problems cloud East European industry

Two years ago, the European Association for Business Research, Planning & Development in the Chemical Industry (formerly the European Chemical Marketing Research Association), set Budapest as the site of its annual conference, little dreaming of the tumultuous changes that would sweep Eastern Europe. However, late last month at the group's conference, high on the agenda was prospects for the chemical industry in Eastern Europe, and western industry's role in those prospects.

Budapest is probably the best place to begin an exploration of the Eastern European industry. The city, awash with architectural riches, sometimes exuberantly decorated, has an impoverished, poor-cousin aura about it. Nonetheless, its people are well-educated and highly cosmopolitan, well conscious of being "European"—and eager to accomplish full integration with their western neighbors as quickly as possible, despite such problems as the lack of hard currency and diminishing supplies of Soviet energy and feedstock materials.

The chemical industry will be a particularly important part of the transition to internationalism, said Gábor Naray-Szabó, president of the Hungarian Chemical Society, in his keynote speech. Naray-Szabó is also managing director of Bionavion, the Hungarian subsidiary of U.S.-based Navix, a biochemicals firm, and so he spoke as both a research chemist and as an industrialist.

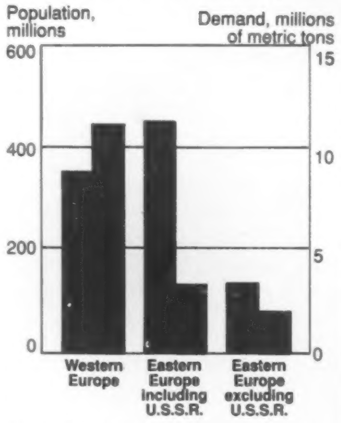
According to Naray-Szabó, in 1987 the chemical industry accounted for 8% of Hungary's gross national product and 18% of its gross industrial product. Free-currency exports of chemicals almost doubled between 1980 and 1989; last year, chemicals made up 24% of the country's exports, having surpassed machinery and food products in the course of the decade.

Total chemical production in the country was worth $4.6 billion in 1988. Pharmaceuticals was the dominant sector at 30% of production, followed by plastics, including rubber products, at 18%, and organic chemicals at 15%. Fertilizers and pesticides as separate categories each accounted for less than 10% of total production, although as an overall "agrochemicals" category they would have rivaled plastics in production value.

Naray-Szabó gave a candid look at the prospects for the Hungarian chemical industry, which are clouded with problems. Among the problems facing the industry in its transformation into a modern, competitive one, is a serious need for capital investment, entrepreneurial management, and well-trained research and work forces. The well-trained researchers are already there, he maintains, but capital and management skills can only come from external investors.

The chemical industry contains many candidates for western investment through privatization, either acquisitions or joint ventures. As for management, he contends that "the majority of the top management in the chemical industry is unable or not willing to keep up with the fast switch from a centralized planning system to a market-oriented economy." Managers selected by officials of the ruling party in the past have conformed with communist traditions: loyalism, mediocrity, and in-

Potential polyolefins growth is large in Eastern Europe



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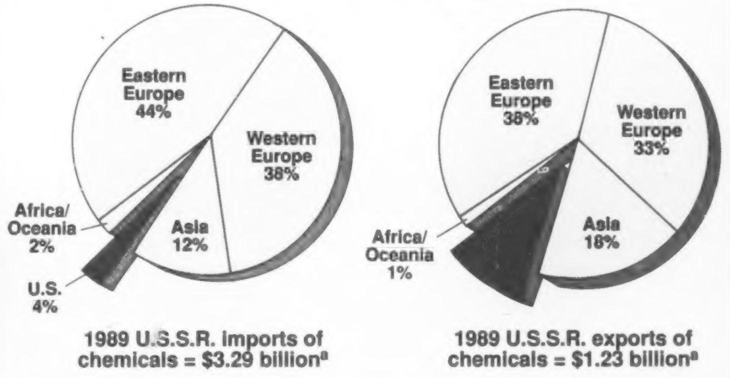
U.S. figures small in Soviet chemical trade



1989 U.S.S.R. imports of chemicals = $3.29 billion[a]

1989 U.S.S.R. exports of chemicals = $1.23 billion[a]

[a] Based on Soviet trade and investment transactions exchange rate, $1.00 = 1.8 rubles. **Source:** Niitekhim, U.S.S.R.

flexibility. The number of western-type entrepreneurial managers remains low, although, over time, training will help redress this lack.

However, the knowledge facing most people in the Hungarian chemical industry is that the industry is in dire need of new capital investment, particularly in environmental protection and cleanup.

Western companies can find good opportunities to invest in the industries in Eastern Europe, suggests Walter Kadl, president of Petrochemie Danubia, based in Schwechat, Austria, near Vienna. Eastern European markets are particularly attractive for chemical companies, says Kadl, because of the low per capita consumption of chemical industry products. The implication: There is much room for growth within those countries.

Petrochemie Danubia's specialty is polyolefins, and Kadl presents some estimates for 1989 demand for these and other commodity thermoplastics in Europe. As a whole, the continent consumes some 25 million metric tons of commodity thermoplastics, including polyolefins, polyvinyl chloride, polystyrene, and styrene copolymers. Polyolefins are the largest single segment, with annual consumption of more than 14 million metric tons—58% of the total. Of the olefin polymers, low-density polyethylene is the most important, with 7 million metric tons, followed by polypropylene, 4 million metric tons, and high-density polyethylene, just under 3.5 million metric tons. By comparison, annual consumption of polyvinyl chloride is about 6.5 million metric tons, and of polystyrene 3 million metric tons.

"When we compare the consumption figures for Eastern and Western Europe with the respective population figures, we can see the huge potential existing in Eastern Europe," Kadl says. "The picture is certainly distorted somewhat by the inclusion of the U.S.S.R, but even without the U.S.S.R., the basics remain the same."

In contrast to the developing Hungarian investment scene, the Soviet Union still offers only limited opportunities. That was the gist of presentations by Viatcheslav M. Sokolsky and Valentina A. Gavrilenko, of Niitekhim, the Moscow-based Research Institute for Economic Studies & Information in Chemical Industry.

According to Sokolsky, Soviet chemical production in 1989 was worth about $27.8 billion (based on Soviet trade and investment transactions exchange rate, $1.00 = 1.8 rubles) with production by more than 1000 enterprises. Some 53% of output was accounted for by enterprises under the jurisdiction of the recently reorganized Ministry for Chemical & Petrochemical Industry.

R&D in Soviet chemicals is carried out by more than 100 R&D organizations, and a number of academic and educational institutions. However, emerging new processes and products have a hard time being put into effect. To introduce an innovation into production in the Soviet chemical industry takes as much as 15 to 20 years, according to Niitekhim estimates; the lifetime of technological processes has been shrinking, from 15 years in the early 1970s, to a predicted seven to eight years in the coming decade.

The U.S.S.R. is one of the leading producers of chemicals in the world, with a heavy emphasis on large-tonnage products, such as ammonia, methanol, benzene, and fertilizers. Basic chemicals in 1989 made up 36% of total production; polymers, 28%; and agrochemicals, 13%.

However, although a leading chemicals producer, it lags behind all large and even many small advanced countries in exporting. Chemicals in 1988 made up only about 4% of total Soviet exports, while they were 5.1% of imports, thereby ringing up a trade deficit in chemicals that has more than doubled during the 1980s.

Medical and pharmaceutical goods, and plastics and synthetic resins accounted for nearly half the imports. On the other hand, fertilizers made up nearly 40% of Soviet chemical exports, followed by inorganic chemicals at 19%. As Gavrilenko points out, in the 1980s the U.S.S.R. has taken a world lead in ammonia supply and in several other areas: Its share in the world trade of technical carbon amounts to about 20%, methanol 17%, and synthetic rubber 10%.

Chemical trade with the U.S. and Canada has grown little, she says, and almost not at all over the decade with Japan. It has picked up significantly, however, with developing countries. For example, by the end of the 1980s, India has become a major supplier of chemical products to the Soviets, with trade exceeding the 1980 level by nearly five times.

Niitekhim predicts that, given the Soviet Union's huge natural resource base, it will continue to be a major supplier to the world market of large-tonnage, energy-intensive chemicals such as methanol, ammonia, urea, and acetic acid, and of polymers such as polyethylene, polypropylene, and polyvinyl chloride.

Patricia Layman

France promotes south coast chemical region

Though ethylene profit margins are being squeezed worldwide, the Port of Marseilles Authority in southern France is seeking a company to construct a new cracking unit in the region to promote further development of a massive chemical complex.

Jean Rousset, president of the authority, told a press conference near Marseilles that two crackers, one operated by Naphtachimie, a joint venture of Atochem and BP, and one by Shell together produce more than 1 billion metric tons of ethylene annually. Although this represents some 36% of French ethylene production, it is already committed. Much of this ethylene as well as some 695 million metric tons of propylene is used locally to produce polyethylene and polypropylene. However, says Rousset, to develop the area further, "a third cracking plant is now necessary." About 70% of the more than 18,000 acres of land that the Port Authority owns at Fos is available for long-term lease.

The authority is a French government agency that operates three industrial zones and their associated ports—Berre, Lavera, and Fos—as well as the general cargo and passenger port of Marseilles on the Mediterranean coast of France. Among the advantages of the industrial zones, it says, are inexpensive energy, plentiful water, and new port installations in a region that is strategically located for both the import of feedstock and the export of petrochemicals. Operators in the area confirm the region's advantages and complain only of occasional power outages, particularly in the summer. Power officials plan to upgrade electrical reliability.

Petrochemical capital investments in the industrial zones topped $1 billion between 1985 and 1988.

Marc Reisch

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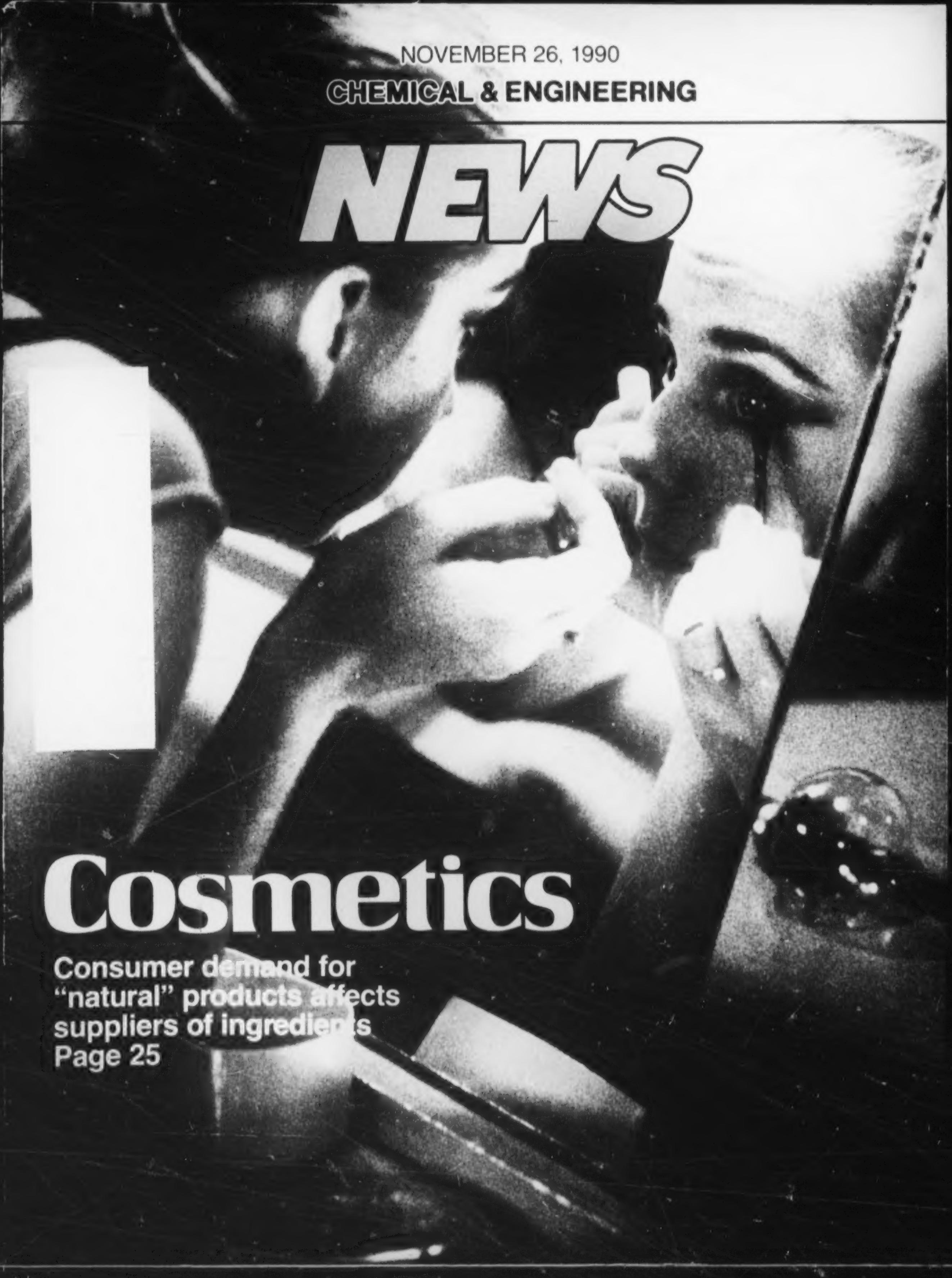

Cosmetics

Consumer demand for
"natural" products affects
suppliers of ingredients
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Volume 68, Number 48
CENEAR 68 (48) 1–76
ISSN 0009-2347

CHEMICAL & ENGINEERING NEWS

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director
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Subscription Rates 1990. Printed editions: nonmembers U.S. 1 yr. $60, 2 yr. $108, outside U.S. 1 yr. $93, 2 yr. $174. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3–10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $9.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Divine right of chemists

Just when I had given up on C&EN because of your advocacy of the "handout mentality" among chemists, along comes a breath of fresh air. The commentary by ACS president Paul G. Gassman (C&EN, Oct. 8, page 35) brings some welcome balance to the flurry of recent letters and articles you have printed on the "God-given privileges" that chemists are purported to enjoy. Perhaps when ACS members stop complaining about the inaction of government and begin increasing their own individual efforts to set things right, we'll no longer have to be concerned about our public image.

Indeed, I believe that the majority of chemists recognize the rewards of individual efforts. Unfortunately, it's that vocal, complaining minority that seems to be the most newsworthy. Congratulations to Gassman for taking the lead on recognizing the nature of the problem.

Joseph A. Curiale
Yorba Linda, Calif.

Paul Gassman was a bit off base when he stated in his recent ACS Comment that the belief in the "divine right of chemists" is not restricted to academic chemists or industrial chemists. Indeed, in my 40 years as both an academic chemist and an industrial chemist I found the divine right business prevalent mainly in academia. I spent the last 34 years with hundreds of chemists in industrial research, and the very few that I knew who exhibited the divine right concept ended up as university professors.

It is my observation that today's average industrial chemist is perhaps too inclined to exhibit humility.

Joseph E. Dunbar
Midland, Mich.

The ACS Comment column, "No divine right of chemists," by Paul G. Gassman, ACS president, saddened me. Gassman's plea for his fellow chemists to join him in feeding on taxpayer's dollars at the federal trough made it seem hopeless that we would ever restrain the growth of our central government. His advice that "in order to obtain increased funding, everyone who expects to receive federal funding must personally help" was disheartening. It was a classic example of groveling for a forced share of everyone's income via the Internal Revenue Service. And this sage advice comes from the president of the American Chemical Society—one of thousands of groups who are all equally convinced that their special interest is of paramount importance.

I urge every reader to heed the advice of William Simon, former Secretary of the Treasury: "Stop asking the government for goods and services, however desirable and necessary they may seem to be. They are not free. They are simply extracted from the hide of your neighbor—and can be extracted only by force. If you would not confront your neighbor and demand his money at the point of a gun to solve every new problem that may appear in your life, you should not allow the government to do it for you. ... This one insight understood, this one discipline acted upon and taught by millions of Americans to others could do more to further freedom in American life than any other."

James Steger
Virginia Beach, Va.

The outgoing ACS president's comment does great injustice to the average hardworking ACS members—whether in academe, industry, or government. For the past 20 years, I have promoted ACS policies to assure professional treatment of chemists. I have never met anyone in our profession who would have claimed any divine right; they only asked for human decency and fairness. The quotes in the comment are, at best, out of context. For example, instead of "There should be no unemployed chemists," it should read, "It is better to have a shortage of chemists than unemployment in chemistry"; or instead of "Chemists should be paid more," the proper quote is, "Chemists should be paid in accordance with their education and contribution to the society."

The problem is that the outgoing president visualizes a utopian state where every action is based on divine justice—where rewards and punishments are meted out fairly. Some of the ivory towers have especially high parapets; therefore, it is understandable if they limit one's view of real life.

Unfortunately, we live in an imperfect society where we need some laws, rules, and regulations to make fair play possible. Many middle-aged ACS members would have welcomed if "past and present accomplishments" would have been the factors to determine their value for their former organization. However, they can readily testify from their own traumatic experience that "What have you done for me today?" was literally the single deciding question. Yes, salary

Congress Sends Mixed Signals on USDA's Competitive-Grants Program

National Research Initiative has brought new funds to USDA's peer-reviewed grants program, but some fear 14% overhead cap spells trouble

The U.S. Department of Agriculture spent more than $1 billion on research in fiscal 1990, but only about 4%—the $40-odd million from the Competitive Research Grants Office (CRGO)—was distributed through a competitive peer-review process open to all scientists. The bulk of USDA's research funds is directed to land-grant universities and to its own extensive research facilities or is earmarked as "special grants" that support the pet projects of this Senator or that Representative.

However, that may be changing. A new National Research Initiative for fiscal 1991 has significantly boosted CRGO's budget to $73 million in the agriculture appropriation bill recently signed into law by President Bush. That's still a long way from the $100 million the Administration wanted for the program and way below the $500 million advocated in a 1989 National Research Council (NRC) report.

One ominous sign amid this largesse is that the new law imposes a 14% cap on the amount of overhead costs universities can recover from CRGO grants. Some observers speculate that that controversial provision may doom the program.

CRGO was established in 1978 in response to criticism that USDA's research programs were not as good as they could be because the funds were not distributed competitively and were not available to the entire scientific community. "The reason the CRGO program is so important is it is the only competitive-review system functioning in the entire USDA," says Paul Stumpf, CRGO's chief scientist. Stumpf, professor emeritus of plant biochemistry at the University of California, Davis, is spending three years in the half-time job of CRGO administrator.

"In the CRGO program we would like to get access to scientists who traditionally carry out basic research," Stumpf says. "Many of these people are not aware of the richness of research in the agricultural sciences. If we could begin to have them do important research on those problems that are relevant to agricultural science we would immediately upgrade the entire agricultural system."

But CRGO has been feebly funded since its inception. The office has been able to fund only 25% of the grant proposals it receives. The average grant size and duration is roughly $47,000 per year for two years—too small and too short to really get a research project rolling. "This job is frustrating because we see so many great ideas that we don't have the budget for," Stumpf says.

Concern over inadequate support for basic sciences applied to agriculture led NRC's board on agriculture to call for a substantial increase in research funding through competitive grants at USDA in its 1989 report. In "Investing in Research: A Proposal to Strengthen the Agricultural, Food, and Environmental System," the board argued that $500 million per year be added to CRGO's budget and that the office itself be given greater autonomy. The NRC panel advised that the new funds be directed toward six program areas: plant systems; animal systems; nutrition, food quality, and health; natural resources and the environment; engineering, products, and process; and markets, trade, and policy.

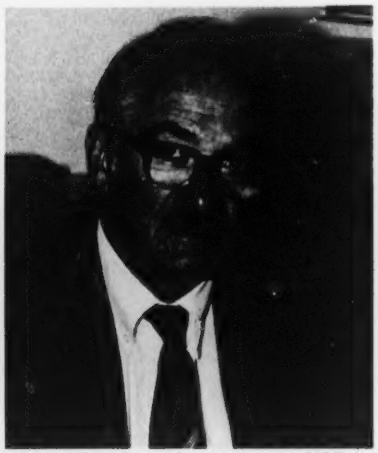
The Bush Administration balked at an additional $500 million, but did ask Congress last January for $100 million for CRGO for 1991 for a new National Research Initiative that incorporates many of the suggestions from NRC, with promises to add $50 million per year in the future. When the smoke cleared from last month's frantic budget negotiations, CRGO ended up with $73 million for fiscal 1991—and with a cap of 14% on the indirect costs universities may charge the federal government for CRGO grants.

"Seventy-three million dollars is

Competitive-grants budget up 72% at USDA

$ Thousands	1991 enacted	1991 request	1990 enacted
Plant systems	$35,000	$ 50,000	$ 7,751
Plant genome mapping[a]	11,000	15,000	b
Alcohol fuels[a]	514	c	507
Soybean research[a]	493	c	487
Animal systems	20,000	30,000	4,937
Brucellosis[a]	475	c	469
Natural resources & environment	14,000	15,000	b
Nutrition, food quality & health	4,000	5,000	1,481
Biotechnology	d	d	18,775
Forestry	d	d	3,949
Stratospheric ozone	d	d	3,653
Pest science	d	d	1,975
TOTAL	$73,000	$100,000	$42,521

a Programs specifically earmarked in appropriations bill. b New program. c Not earmarked in budget request. d Now incorporated in other competitive-grants programs such as plant and animal systems. **Source:** U.S. Department of Agriculture



C&EN staff photo

Stumpf: only such program in USDA

obviously a lot less than what we had hoped," says Theodore L. Hullar, chancellor at UC Davis and chairman of the NRC board on agriculture. "We hope next year's budget request will be significantly increased to get back on track toward $500 million."

"The 14% cap is a particularly difficult, disappointing, and discouraging sign," Hullar continues. "Indirect costs are real and have to be paid for from someplace. Universities may not have the money or will have to take funds from other sources that need them. I find as I talk to people a steadily increasing sense of fear and dismay."

That apprehension stems in part from the fear that the idea of an overhead cap will spread to other federal funding agencies with much bigger competitive-grants programs—like the National Institutes of Health and the National Science Foundation.

The only real way the universities have of fighting back, a Washington, D.C.-based observer notes, is to refuse to accept CRGO grants. And that, the rumor goes, may be exactly what Rep. Jamie L. Whitten (D.-Miss.), chairman of the House Appropriations Committee and its agriculture subcommittee, has in mind. "Whitten has always hated the CRGO program because he has no control over where the money goes," the observer says. "He's trying to kill the program by taking away the indirect-cost payments."

Pamela Zurer

Nuclear test raises hackles in U.S.S.R.

The nuclear weapons test conducted by Soviet weaponeers at their test site in the Arctic on the island of Novaya Zemlya on Oct. 24 has triggered a lively public debate within the Soviet Union as well as concern in neighboring Nordic countries.

It has raised the question of "Who's on first?" in regard to what the Soviets have long considered a very important arms control goal—the banning of all nuclear weapons testing worldwide as soon as possible.

The test, which was underground, was relatively large, about 85 kilotons. It was the first Soviet nuclear test in more than a year.

The blast came six days after Soviet President Mikhail Gorbachev had reiterated his strong commitment to a global test ban. It also came a few weeks after the Supreme Soviet had ratified a bilateral 1974 treaty with the U.S. limiting the size of nuclear tests to 150 kilotons and called upon "parliaments" around the world to work toward an end to all testing.

The test also came just a few weeks before Gorbachev will go to Norway to receive his Nobel Peace Prize. The northern fringes of Norway, Sweden, and Finland are all within a few hundred miles of the Novaya Zemlya test site. These nations, along with Denmark and Iceland, had earlier this year protested the possibility that the Soviets would shift the bulk of their testing to Novaya Zemlya in the wake of the closing of their major test site in Kazakhstan because of intense public pressure.

Gorbachev's Oct. 18 statement came in a personal letter to the U.S. and Soviet cochairmen of International Physicians for the Prevention of Nuclear War. The letter pointed to an earlier 18-month moratorium that the Soviets had put on their own testing and to the lack of Soviet tests for the past year. It also stated, "We are not yet, regrettably, at a point where the U.S. would accept a total prohibition of nuclear testing. It is my intention to once again call the attention of President Bush to this problem at our next meeting."

The U.S. has had no pause in its nuclear weapons testing in recent years. It maintains that such testing is essential as long as its security relies on nuclear deterrence. There have been eight announced tests at the Nevada Test Site this year. The latest, conducted earlier this month, was of a British warhead and it was delayed briefly by British and U.S. protesters who penetrated the testing site.

One of the first Soviet officials to protest the Oct. 24 test was Nikolai Vorontsov, who is chairman of the U.S.S.R. State Committee for Environmental Protection. In a televised statement he claimed that environmental agencies were not given advance notice of the test, as they apparently should have been, and that neither local nor Russian state officials consented to it. In Vorontsov's opinion, the test is another blow by the military-industrial complex against President Gorbachev.

In another telecast, three Soviet cosmonauts broadcasting directly from space dropped their prepared program. Instead they protested the nuclear test and supported the drafting of a "people's treaty" outlawing the development, production, and testing of nuclear weapons. Soviet television also carried live a contentious discussion of the test by the Supreme Soviet.

At a news conference, deputy foreign minister Viktor Karpov stated that the Oct. 24 test will be the "sole and final" one for 1990. He stressed the Soviet Union's continued advocacy of a total ban. However, he added that, with no real prospects for a global ban at this time, the Soviet Union will not commit itself to another unilateral testing halt. But it would accept a bilateral moratorium with the U.S.

A C&EN poll of arms control experts brought no consensus on the implications of the Soviet test. One suggestion was that the weapon had been in place underground ready for testing for more than a year, that there was no way to get it out, and that the only way to get rid of it was to set it off before the test site closed down for the winter.

Michael Heylin

PRODUCT REPORT

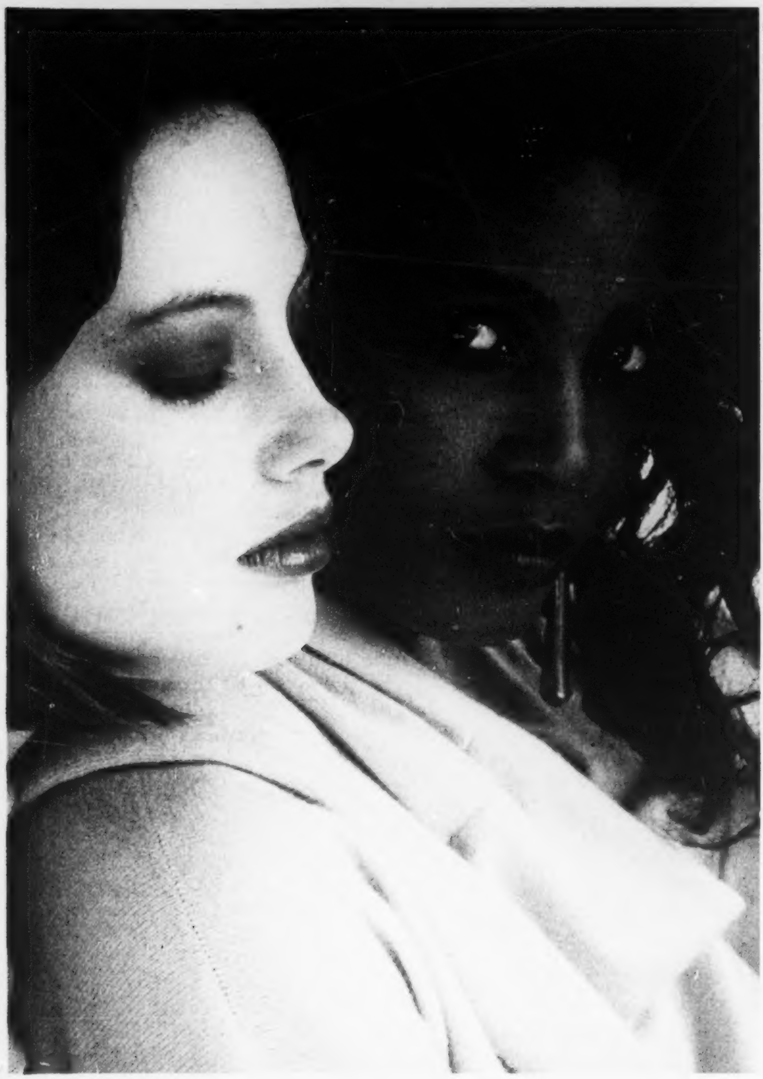


Photo by Barbara Daly for The Body Shop

Move to Natural Cosmetics Challenges Ingredient Suppliers

Susan J. Ainsworth, C&EN Houston

Business is becoming more complex and more competitive for companies that market cosmetics and toiletry products and the ingredients used to formulate them. Traditionally, cosmetics and toiletries have been expected to make the user appear more attractive—to cover skin imperfections, add color to the face or impart a pleasant scent to the body, for example. But over the past few years, there has been a decided move toward developing cosmetics that claim to incorporate new technology and promise to do something good for the user's body. That movement is continuing and strengthening.

Marketers also are responding to consumer demand for cosmetics that contain more botanicals or other natural ingredients. And in keeping with a "greener" public today, products are designed to be more in harmony with nature, touting recyclable packaging, and claiming not to have been tested on animals.

Still, these two trends—more technological and more back-to-basics—do not necessarily contradict one another. "A lot of technology goes into formulating a natural product," points out Frank Nowak, marketing manager of cosmetic polymers at National Starch & Chemical, Bridgewater, N.J. And, he adds: "There are probably just as many marketing claims and benefits derived in a natural as in a nonnatural product."

To be sure, these new trends mean corresponding challenges for the suppliers of raw material ingredients. Nowak observes that these changes "place quite a demand on the formulator and the marketer of a cosmetic product. It's becoming a very complex and sophisticated market."

It is also becoming an extremely competitive market for companies that peddle their wares to the cosmetic and toiletries industry, which had 1989 U.S. sales of $17.5 billion, according to Kline & Co., Fairfield, N.J. Not only do companies need to vie for the development of ingredients that fit with these new cosmetic trends but, as merger activity continues, they also must market these products to a shrinking number of cosmetic companies.

On top of all this, the market is maturing. The U.S. market for cosmetic and toiletry raw materials reached $1.6 billion in 1989 and is projected to increase to almost $1.8 billion in 1994. This represents real growth of only about 2% annually, according to Kline. "The market for chemical ingredients cannot grow any faster than the cosmetic industry itself," which is growing at roughly 2% per year, observes Mark Chandler, an industry specialist with ICI Americas' specialty chemicals division.

It is difficult to predict how well

Cosmetics industry faces its own "green revolution"

There's no doubt about it. Today's consumer is concerned about the environment—possibly much more so than at any point in history. That awareness has been heightened by dramatic events such as growth of the hole in the ozone layer, smog problems in the world's major cities, and a growing number of chemical accidents. These concerns are being increasingly reflected in consumers' buying patterns.

It's not surprising, then, that natural or botanically derived cosmetic products are gaining popularity in the U.S. They are already popular in Europe, where the environmental movement has had a head start. Equally desirable to today's consumer are products that are not tested on animals and are sold in pared down and recycled packaging. Says Michael Waldock, president of the U.S. arm of The Body Shop, a U.K.-based cosmetic and toiletries company: "You've got really quite an alert consumer now and I think that natural products fit very well with where their thinking is."

Consequently, cosmetic companies are clamoring for natural ingredients that not only will be efficacious but also will enable them to win the favor of a growing legion of environmentally conscious consumers.

Last August, Estee Lauder Co. formed a new unit—Origins Natural Resources Inc.—so as to address all of these environmentally sensitive trends under one umbrella. Origins says it will embrace "the needs of the consumer interested in the possibilities of natural solutions for skin care, including body products, aromatherapy, and certain innovations in the makeup area."

Origins says its products rely heavily on natural plant materials—roots, stems, bark, and fruit. The company also claims to use "plant infusions" in place of water in its formulations. In general, says Origins, cosmetic formulations add 30 to 80% water, "an essentially nonfunctioning ingredient." In addition to essential oils, plants have other beneficial materials that are soluble in water. These can be hydrating, calming, soothing, or astringent, says the company. "Origins uses these infusions instead of water to complement the action of the essential oils and extracts."

"Origins has made a commitment to the preservation of Earth, animals, and the environment," says the company. To this end, "Origins' products contain no animal-derived ingredients, and have never been, or ever will be, tested on animals. Origins' packages and shipping materials are made of recycled papers. We encourage [the customer] to return empty packages to the counter to be recycled."

The Body Shop (Wick, Littlehampton, and West Sussex, England) has been making the same pledges to its customers. And the company, which has sales of $143 million per year, had been knee-deep in many socially conscious projects long before the environmental movement was in vogue.

The list of The Body Shop's endeavors keeps growing. Early in 1991, the company plans to unveil a group of products, including a new mother and baby line, that will contain natural raw materials derived from the world's rain forests. "It's a shame that a tree is worth more as a log" than as a resource-bearing plant, Waldock says. "So if we can buy crops from these trees," which can be harvested without harm to the tree, it preserves the forests and it helps support the surrounding communities. Also, as its U.S. presence continues to blossom, the company is researching the natural resources that the Native Americans and early settlers might have used for skin and body care.

The Body Shop has been highly successful in the marketplace. Waldock reports that "the company has grown nearly 50% (compound sales growth) year-on-year for the past 10 years." Since 1976 when the company was founded, it has grown to include more than 500 shops in 37 countries around the world. "Our 27 stores in the U.S., which have been open little more than one year, are doing 30% better than the previous year. And that's in a retail market which is either declining or static," he boasts. Perhaps this is proof positive that marketing anything construed as a natural cosmetic can be lucrative.

Indeed, chemical suppliers with the right stuff can also cash in on the naturals trend. Good natural ingredients are in high demand. "The use of natural raw materials does restrict a cosmetic company's options. They simply provide fewer tools to work with," notes National Starch's marketing manager of cosmetic polymers, Frank Nowak.

the business will fare in the near future, say industry sources. "We are anticipating future growth, but I'm holding my breath. I'm concerned about the 1990s. The oil situation in the Middle East could worsen and the economy is turning down, so it's really hard to pinpoint short-term growth," says a marketing manager at a chemical ingredients supplier. "Everyone says cosmetics and toiletries is a recession-proof industry," he adds, "but that's not exactly so."

Still, certain parts of the business won't be greatly affected by an economic downturn, predicts Matthew Jurczyk, product manager for detergents and surfactants at Akzo Chemicals, Chicago. "Let's say the economy goes into a recession. Sales of durable consumer products like autos may drop dramatically. But you won't see that kind of impact in the hair care category, for example, because these products are almost necessities." Consumers may change brands in this scenario, he adds, but "we expect no violent swings in sales levels of cosmetic and toiletry products."

The cosmetic raw materials business does have its bright spots. For example, specialty raw materials is a segment that is experiencing roughly a 60% higher growth rate than the overall cosmetic and toiletry raw materials market, according to Jacqueline Franklin, a consultant with Kline. Specialty raw materials—such as hair care polymers, mild surfactants, cosmetic active ingredients, thickeners, and ultraviolet light absorbers—account for more than 50% of the raw materials used in cosmetic and toiletry formulations. She says many of these specialties have experienced double-digit growth over the past few years, and are forecast to have continued strong growth through 1993.

According to Kline, hair care polymers represent 35%—the largest chunk—of the specialty ingredients market. A separate cosmetic addi-

On the ingredient side of the market, one company that says it is well positioned to take advantage of the demand for natural ingredients for cosmetics is Henkel. The company has had a long history of producing chemicals from natural resources such as coconuts, tallow, and soybeans. And in keeping with that theme, Henkel's Emery Group is poised to build the first major plant to make alkyl polyglycosides (APG), extremely mild surfactants that are made using natural materials derived from coconut or palm kernel oil feedstocks, says Tony DeRosa, vice president and general manager of Henkel's Cospha Group. The first applications, he says, will likely be in foaming-type cleansing formulations in shampoos, bubble baths, and hospital or feminine care preparations.

It's important to realize, say chemical suppliers, that just because an ingredient is natural it is not always better and safer. Synthetic ingredients often have important advantages over their natural counterparts. For example, Akzo makes a consistency regulator that is "essentially a synthetic beeswax," says Matthew Jurczyk, product manager for detergents and surfactants at Akzo Chemicals. Like beeswax, Akzo's material helps build up thickness in formulations to make rich creams. But unlike beeswax, Akzo's product provides batch-to-batch quality, which is important to formulators who want their finished products to look the same on any given day and in any given marketing location, he notes.

Other naturally derived products also have come under recent scrutiny. For example, lanolin—a fat obtained from the wool of sheep and long used as a softening agent in a variety of cosmetics and toiletries—can be a skin sensitizer. Further, there has been some concern about residual pesticide accumulation in lanolin. In response, Akzo markets its Elfacos ST, "which can be loosely translated to be a synthetic lanolin replacement with a good safety profile," says Jurczyk.

Increasingly, companies opt to work the kinks out of the natural ingredients rather than switch to a synthetic formulation, knowing full well the marketing power inherent in the word natural. Henkel's Cospha Group has introduced a new line of ultrahigh purity lanolin and lanolin derivatives that are specially refined and guaranteed to be nonsensitizing and to have very low pesticide levels.

Although its strength lies in synthetic cosmetic ingredients, Akzo is no exception to the natural ingredient production trend. For example, it makes hair conditioning additives based on cocoa and soy feedstocks. These natural ingredients provide the same general level of functionality as derivatives from synthetic feedstocks, but "they will appeal to the consumer who knows they are derived from plant sources. It's really a matter of personal choice on the consumer end," adds Jurczyk.

Plant-derived ingredients are generally more popular with consumers owing to a misconception that animals are harmed in the process of collecting animal proteins, which have long been used in hair care, say some company sources. "Many, if not most, marketers of finished goods have eliminated animal-derived raw materials, simply because of the negative stigma attached to these ingredients," says one chemical supplier. But plant proteins such as those derived from soy act similarly, the source adds, so substitution is not really a problem.

Indeed, one must look closely at product labels to learn that all natural products are not created equal. Some marketers, for example, put a small amount of something like chamomile in a product and then tout the ingredient in large letters on the label. Waldock notes, "What they don't realize is that you must put a lot of chamomile in a product to make it work." Natural products "have really got to have the right formulation, not just the label."

Some chemical suppliers question whether the trend in the use of natural ingredients will be a lasting one. "I'm not sure demand for natural ingredients is growing significantly. Companies are taking the opportunity to market the fact that they have these ingredients in their products, and natural ingredients are certainly more visible. Whether they are experiencing true growth, I don't know at this point," says Bill Siefring, associate director of cosmetic ingredients at Calgon Corp., Pittsburgh, which markets water-soluble polymers and preservatives for hair and skin care formulations.

But Waldock disagrees: "A lot of manufacturers have been saying that [the natural strategy] won't work, that it's a fad. The fact is that consumers have always been interested in products that use ingredients that their grandmothers talked about, and rising environmental awareness has been further driving the trend."

---

tives study, done last year by Freedonia Group, Cleveland, Ohio, projects that in the U.S. the hair polymer segment will grow nearly 11% per year through 1992. Sales of hair care products nearly doubled between 1982 and 1987 with the introduction of mousses, Freedonia Group says. That's good news for companies like National Starch, which specializes in fixative hair resins.

Mild surfactants and cosmetic active ingredients together make up a quarter of the swiftly growing cosmetic specialties segment, according to Kline. Consequently, companies like ICI, which has been traditionally strong in skin care ingredients such as emulsifiers and emollients, are expanding their product portfolios to include more specialty surfactants. "We produce some mild surfactants for shampoos. They have been a lesser part of our business, but could grow significantly," says ICI's Chandler. The company, he notes, is expanding capacity at its Wilmington, Del., facility to broaden its range of surfactants.

"Specialty chemicals are of particular interest to cosmetic chemists because they can be used in cosmetics and toiletries to create distinct efficacies in finished cosmetic products," according to Franklin. Cosmetic and toiletry trends have resulted in a shift in the type of specialty chemicals demanded by personal care formulators. These changes in demand create opportunities for innovative raw material suppliers who anticipate and then address the unmet needs of the cosmetic and toiletry industry, she adds.

Despite the increasingly competitive nature of the cosmetic chemicals business, "it can be a real growth business for the raw material supplier that can help a cosmetic company advance the state of the art," says Akzo's Jurczyk. "We are in anything but a stagnant industry."

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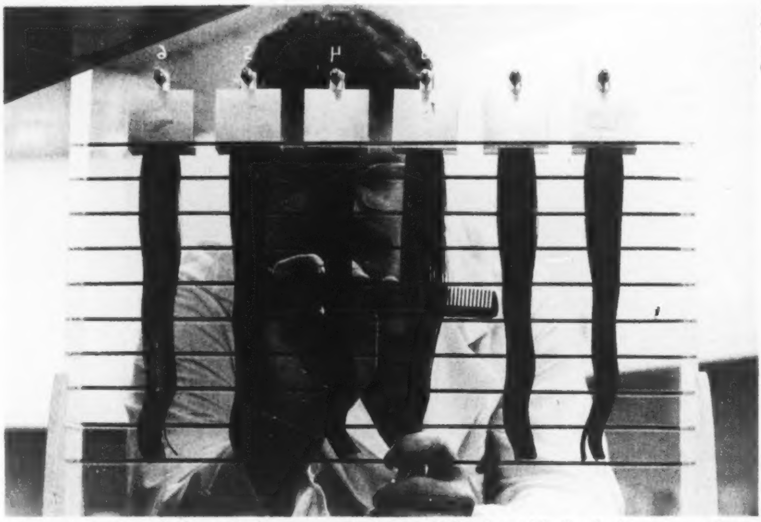
Calgon photo

Technician uses hair swatches to evaluate conditioning aids for hair care products

Indeed, cosmetic companies are calling on suppliers to help them create products that do something good for the body rather than just making it look better. These products often go so far as to blur the line that separates cosmetics from pharmaceuticals.

As cosmetic companies make more sophisticated claims for their formulations, they need chemical suppliers more than ever to help them to back up those claims to the Food & Drug Administration, which is keeping closer tabs on these products. "The industry is becoming more aware of the fact that if they make certain claims, they must be more astute in justifying and proving those claims," observes Bill Siefring, associate director of cosmetic ingredients at Calgon (Pittsburgh).

"The really good cosmetic companies are more careful with claims," echoes Tony DeRosa, vice president and general manager of Henkel's Cospha Group. And, accordingly, Cospha does much scientific research to demonstrate the efficacy of its treatment chemicals, he stresses. "We want to differentiate ourselves. We don't make products that just meet a specification, we go further to guarantee a result."

The majority of these advanced, efficacy-promising products are skin care formulations such as sunscreens, antiaging compounds, skin repair products, and moisturizers that aim to prolong the good health and appearance of skin. One example is L'Oréal's Plénitude facial skin care line, which the company claims will "significantly improve the look and feel of those areas of your skin most vulnerable to aging."

L'Oréal claims its Action Liposomes product, for example, is chock-full of microspheres that have an inner core of active agents that permeate the skin's surface. When in place, the liposomes "slowly dissolve and release lipidic and hydrating agents which target areas of skin that appear to be most in need of help; increase skin elasticity; enhance the appearance of skin's surface texture, making it younger and healthier looking; equalize the skin by reducing dryness and minimizing oiliness; and contain sunscreens to block UV light," the company says.

Two factors may be driving this facial skin care trend. For one, consumers are becoming more aware of the dangers of prolonged exposure to the sun and are demanding products that will counteract or repair damage that has already been done.

And second, the first of the baby boomers are becoming graying consumers, concerned about drying skin and looking younger. "Though the great explosion in 'gray panther' population is not expected to happen for several years, the numbers are compelling. The aging of Ameri-

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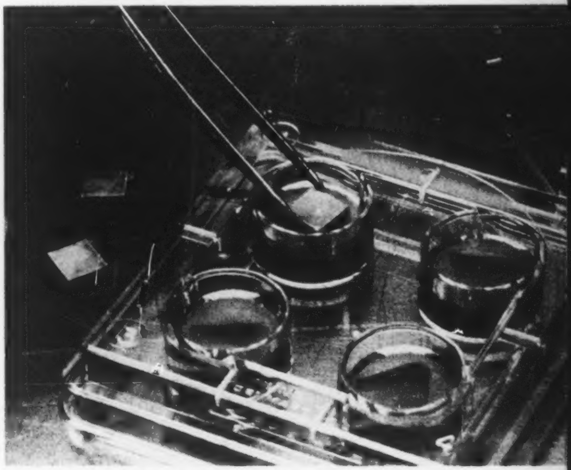
ca is under way and will accelerate: Companies will find, out of necessity, that they must successfully target 'gray panthers,' " according to a report done earlier this year by the New York City-based consulting firm Frost & Sullivan.

Indeed, chemical suppliers and cosmetic companies realize that consumer demand for advanced skin care products is growing. Skin care sales are growing 10% per year currently, well outpacing the average revenue growth for the cosmetic and toiletry industry overall, according to Henkel's DeRosa. Sales in the mass market skin care sector were flat in early 1990 after a 13% increase in 1989 because of some inventory cutbacks, notes Diana K. Temple, who tracks the cosmetic and toiletry industry as a vice president of financial analysis for Salomon Brothers. But new product activity has been strong and "we project total skin care sales at $4.54 billion in 1990, up 8%," Temple adds.



Henkel is developing many alternatives to animal testing, including one using skin cultures

Within the skin care segment, many cosmetic companies are targeting men, who are buying more of these products. Total factory sales of men's toilet soaps, skin moisturizers, and antiperspirants and deodorants exceeded $2.1 billion in 1989, and Frost & Sullivan forecasts the market will surpass $2.8 billion by 1995. The fastest growth will occur in the smallest category, skin moisturizers—$335 million in 1989 and a predicted $522 million by 1995, according to Frost & Sullivan.

Interestingly, men seem to respond to the growing group of products with performance-oriented claims, notes the consulting firm in its study on men's skin care products in the U.S. carried out this past June. The report maintains, "Men's skin care product usage will increase more rapidly if marketers adopt performance-oriented claims to sell to men, rather than cosmetic/appearance-oriented claims which appear to have been translated directly from female products." The study concludes that "for men's skin care products, in general, marketers have only begun to tap the potential."

Recognizing that skin care is "one of the most rapidly growing segments of cosmetics," National Starch, which maintains its strength in hair care resins, has embarked on a "major refocus on skin care," notes Nowak.

Under the skin care umbrella, one of the buzzwords that is driving cosmetic companies' product development in this area is "moisturization." ICI, for example, has helped to develop a new moisturization product. In collaboration with the cosmetics firm Chanel, ICI came up with a moisturizing complex from propylene oxide and a companion emulsifier system, based on liquid crystal technology. "ICI Specialty Chemicals were of invaluable assistance in the formulation of Hydra-Systeme by giving us a liquid crystal system from which we could develop a base perfectly adapted to the hydrating activity we wanted to create in our product," says Jean-Claude le Joliff, cosmetology research director for Chanel. Chanel chemists were able to develop a base that prolongs the hydration boost inherent in multiple-phase systems and to formulate a product active on three different skin levels: at the surface, within the epidermis, and at the epidermal base.

In the quest to develop better moisturizers, this past spring National Starch launched its Dermacryl 79 multifunctional skin care polymer. The product forms a film or moisture barrier on the skin, reducing transepidermal water loss. "So the skin is softened by its own moisture," says Nowak. About 50 cosmetic companies in all parts of the world are working with the ingredient and National Starch expects that a product containing Dermacryl will soon hit the market.

Product development with a new ingredient, however, takes time. "Skin care companies tend to move more slowly [with new product introductions] than suppliers would like to see," notes Jack Guth, technical manager for specialty polymers at National Starch. "Since the skin is a living, breathing organ of the body, companies are very careful in testing any formulation that will go on skin. We have done our testing and have a very high comfort level with Dermacryl 79. Now companies that will formulate with it need to do their own evaluations."

Besides providing the moisturization properties so in demand, Dermacryl serves several other functions in a formulation that likely will make it very popular in today's market, says National Starch. Multifunctionality is what consumers are looking for in products. That explains the popularity of products like Procter & Gamble's Pert Plus, which combines a shampoo and conditioner in one formulation.

Specialty ingredients dominate cosmetics markets

$ Millions	1989 consumption	% of total
SPECIALTIES	$1200	78%
Organic specialties	310	20
Fragrances	300	20
Surfactants	290	19
Fatty chemicals	145	9
Inorganic specialties	100	7
Biocides	55	3
COMMODITIES	340	22
Organic commodities	215	14
Propellants	70	4
Petroleum products	55	4
TOTAL	$1540	100%

Sources: Kline & Co., C&EN estimates

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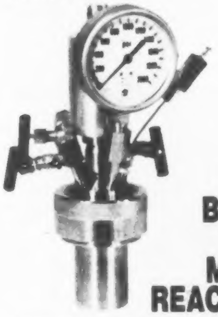

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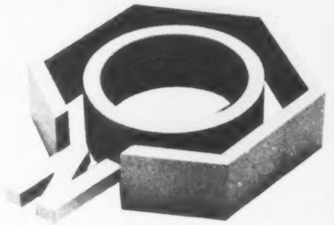
Pyridine and Derivatives



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Multifunctional products are popular with consumers looking to save both money and time. Nowack observes: "Consumers ask themselves, 'Why pay for two products if you only need one?' "

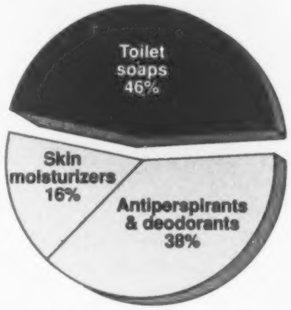
National Starch's Dermacryl 79 seems to be designed for multifunctional products. In certain formulations it serves as "an excellent binder for pigments" used, for example, in makeup and mascara, says Guth. It also resists rub-off, he notes. That means that it releases fragrance over a long period of time. In addition, Dermacryl waterproofs different types of materials such as sunscreens. "We have lab data showing that over 90% of the [sun protection factor] value of a formulation is retained in a standard water soak test."

Indeed, the sunscreen market is a bright spot for the cosmetic industry. According to Salomon Brothers' Temple, "The suntan lotion market grew 14% in 1989, boosted by concerns that exposure to the sun causes skin to age prematurely. Recent research indicates skin can be preserved in a more youthful state by limiting exposure to the sun."

Temple expects growth in sunscreens to moderate eventually as more skin care products and moisturizers incorporate sunscreens. Guth, too, forecasts "real growth in multipurpose sunscreens. More people will start to use sunscreens on an everyday basis."

Along with this trend, he says, there is now a movement in the industry toward inorganic-based sunscreens. Right now the three organic chromophores used are octodimethyl *p*-aminobenzoic acid (PABA), benzophenone, and methoxycinnamate. With sunscreens now being applied to the skin daily rather than just for a few days during a summer vacation, the industry and consumers are concerned about the ability of these chromophores to penetrate the skin and about the long-term effect of using these materials.

Soaps account for bulk of skin care sales to men



1989 sales = $2.11 billion

Source: Frost & Sullivan

Companies are now looking to inorganics such as titanium dioxide, which is considered inert as far as the skin is concerned—it won't penetrate. Dermacryl, he notes, can be used to disperse the TiO_2, which can be used in a micronized form that does not look like "the whitening blob that many associate with TiO_2," says Guth. "Quite a few TiO_2-based sunscreens, including one by Hawaiian Tropic, are coming onto the market; most of the major companies see the appeal in marketing a more natural-type of sunscreen."

Increasingly, cosmetic companies want not just their sunscreens, but also other products to last longer on the skin. For example, Avon Products has launched Color Release long-wearing lipstick and blush that rely on patent-pending, color-encapsulated formulas that actually renew themselves throughout the day, so lipstick and blush look and feel just-applied longer.

The new Color Release line "responds to the needs of today's busy woman and represents the most advanced technology available today," the company says. "With many women juggling more responsibility, putting in long hours and making long commutes, it was no wonder that Avon research among its own color cosmetic consumers indicated that long lasting was a top priority," says Avon's director of color cosmetics, Lynn Kirby.

"Avon has been able to contain moisture and color-filled micro-

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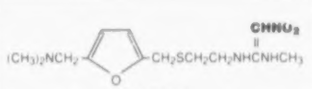

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spheres that act like sponges, so fresh shots of color and moisture are released by the action of talking, drinking coffee, and other typical daily movements," explains Andy Cunningham, Avon's director of research and development for color cosmetics. "Each single capsule consists of 45 to 50% color plus emollients—and there are thousands of capsules in each lipstick. Unlike other lipsticks that make long-wearing claims based on stain, this lipstick has more pure color," Cunningham adds.

And Clinique has introduced its long-lasting Superlipstick. "Made with pigment that won't change color and lubricants that don't blur, it has a behavior pattern of durability with no stain or dryness drawbacks at all," says the company.

Keeping abreast of cosmetic trends and developing ingredients to meet the changing needs of cosmetic companies is an uphill battle for chemical suppliers. Also, the merger activity among cosmetic companies has consolidated the customer base of chemical suppliers.

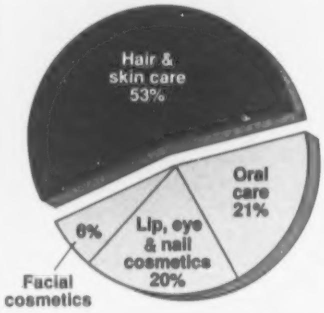
For example, two months ago Swiss fragrances and flavors giant L. Givaudan & Cie. S.A. agreed to buy Fritzsche, Dodge & Olcott from Germany's BASF K&F. And in September, American Cyanamid completed its plan for divesting its Shulton Group of consumer products by agreeing to sell its Breck hair care products line to Greyhound Dial. Countless other cosmetic and toiletries companies have changed hands over the past two years. "The industry is consolidating ... to meet research and development requirements, which are often too costly for small, independent producers," according to the Freedonia Group's report.

For companies looking to cut costs, acquisition strategies can pay off. Consumer companies with popular brand name products are attractive takeover targets because of the longevity of their franchises and the high cost of launching new products, says Salomon Brothers' Temple. Today it is less expensive and less risky to acquire a brand than to launch a new product.

All of this consolidation presents new challenges for the chemical

CIRCLE 39 ON READER SERVICE CARD →

Elderly people use mostly hair and skin care products



1989 sales = $10.9 billion

Source: Frost & Sullivan

supplier. "Fewer, larger customers make the stakes higher," notes ICI's Chandler. For example, an ingredient company might have a solid relationship with a cosmetic company customer, and if the customer is purchased, divisions get merged and a supplier almost has to start all over forging that relationship.

To cement these customer relationships, especially in the more lucrative specialty segments, companies that supply the cosmetic and toiletries industry are stepping up the service component of their businesses. For example, in late 1989 Calgon abandoned its distributor-based marketing system and formed a business unit to focus solely on supplying the personal care industry. This unit includes an R&D group, a technical sales organization, and a product management team, explains Siefring. "It allows us to really focus on customer needs."

"If you're going to be in the specialty business and really be a true specialty company, you've got to have people out there every day, meeting the customers and trying to understand their needs, because they are always changing," Siefring says. Cosmetic companies "come out with new products, and trends change, so we need to keep ahead of the game and bring new things to market with those changes." Kline's Franklin echoes this point: "Specialty raw material suppliers to the cosmetic and toiletry industry can create competitive advantages through an understanding of the service requirements and their role in the product development process."

Increasing competition in an increasingly global industry means more cosmetic and toiletries companies are striving to develop formulations for the international market. Because the costs of developing each cosmetic formulation are so high, companies are getting away from formulations for local markets. To facilitate this trend, ingredient suppliers, like Akzo, for example, make sure all of their personal care offerings are internationally accepted or allowed. This way a customer can use the same raw materials from the same supplier at all manufacturing sites globally. Providing internationally accepted ingredients is a cost for ingredient suppliers and restricts the raw materials tremendously. Companies like Akzo that have a global organization can provide such ingredients, Jurczyk says.

Ingredients that are internationally approved or accepted are becoming few and far between. In Europe, and more recently in the U.S., a number of controversial issues surrounding the cosmetic industry have been heating up.

Currently, FDA's regulatory authority over the cosmetic industry is less comprehensive than its authority over food and drugs. Consequently, in its oversight of this industry, FDA must rely, in part, on voluntary industry cooperation.

The industry is watching with interest Rep. Ron Wyden's (D.-Ore.) attempts to impose more stringent regulations on the personal care products industry, an effort that the Cosmetic Toiletry & Fragrance Association (CTFA) continues to oppose. His draft legislation includes required internal safety substantiation of all cosmetic products; increased FDA access to safety and consumer complaint data; mandatory registration of cosmetic establishments, products, and ingredients; and man-

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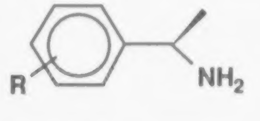

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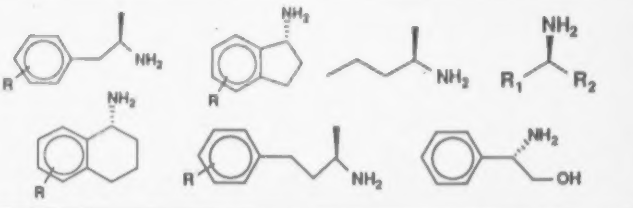

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CIRCLE 31 ON READER SERVICE CARD

datory ingredient labeling for professional products, according to Liz Price, a legislative assistant in Wyden's Washington, D.C., office. To date, Wyden has not introduced any legislation but, adds Price, he plans to introduce a bill in the next Congress.

At Wyden's request, the General Accounting Office initiated an investigation of the adequacy of the industry's regulatory programs. The GAO report, issued last March, noted, "Disagreement continues between FDA and the industry as to the extent of participation in the voluntary registration program. Because FDA cannot mandate participation, it cannot accurately assess how many companies may be avoiding registration. In addition, FDA has not assessed whether industry efforts have resulted in increased reporting of data on safety testing. Because it is a voluntary program, however, FDA will never be able to require reporting from all companies, particularly those that may be least likely to report because they have experienced problems with their cosmetics."

In response to "Wyden's attacks," CTFA says that in 1988 it developed a voluntary ingredient labeling program for professional products. The association also claims to have helped boost industry's participation in the FDA's Voluntary Reporting Program this year. Also, in January 1989 the Cosmetic Ingredient Review, an independent body of experts organized by CTFA, prepared a comprehensive report on some 1000 ingredients identified as potentially toxic substances. However, the CIR report found no major safety concerns with any of these ingredients, says CTFA. FDA has been studying the report, but has committed no resources to do its own safety reviews and ranking.

Separately, the animal rights controversy (C&EN, May 7, page 9) is "taking on greater proportion in the U.S.," says an industry source. CTFA vigorously opposes bills in several states that would restrict or ban the safety testing of cosmetic products on lab animals, or require products to disclose such testing on their labels. To date, no state has enacted such legislation.

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Product Report

Six animal testing bills of special concern to the cosmetic industry are pending in three states: Michigan, New Jersey, and Pennsylvania. CTFA is working closely with its member companies, the Soap & Detergent Association (SDA), and other allies in the effort to defeat these bills. So far in 1990, CTFA says it has been instrumental in the defeat of 12 restrictive animal testing proposals in seven states: Arizona, California, Hawaii, Illinois, Maryland, Massachusetts, and New York.

In response to the animal testing controversy, last year CTFA launched a public affairs legislative educational campaign aimed at legislators and opinion leaders. "This effort is intended to make sure that CTFA's public interest position on human health and safety is heard above the din of misleading information generated by animal activists," says CTFA in its 1989 annual report.

At the same time, the association is continuing its effort to find alternatives to animal testing. This year it completed Phase I of the CTFA Evaluation of Alternatives Program at Battelle Memorial Institute's Columbus Laboratories. "A multiyear endeavor aimed at securing in-vitro alternatives to the Draize eye irritation test, the program will provide CTFA members with information to determine which alternative procedures are most appropriate for use in their product development and safety evaluation programs. Approximately 25 in-vitro protocols have been evaluated in Phase I, using alcohol-containing personal care products," notes CTFA. Phase II, which is now under way, will cover oil/water emulsions, that is, creams and lotions, says CTFA.

In addition, some suppliers are working on novel, in-vitro alternative testing methods in their own facilities. Henkel, for example, is developing three such methods. One uses the membrane of a fertilized egg as a substitute for eye and skin irritancy tests; another involves in-vitro testing of a cell; a third uses tissue cultures.

Says one chemical supplier, what many people don't realize is that "responsible scientists try to limit testing on animals to those things

Calgon researcher checks viscosity of skin care formulation

they are ready to go out into the industry with. For the most part, a company will already have a good feel for the toxicity of a formulation before it tests it on an animal. The testing is a way to confirm your assumption before going on." He adds, "I do feel that until alternative tests can be developed, the industry has to have the option of animal tests to make accurate predictions on how a formulation will affect the user."

While a large number of cosmetic companies tout the fact that their products are not animal tested, in all probability most of the ingredients in these products have already been tested on animals at some point in the past, notes ICI's Chandler. Many chemical companies test the ingredients they supply on animals before they sell them, if for no other reason, he says, than that companies have a responsibility to know of any harmful effects of these materials in order to protect employees who work around these chemicals. Animal testing is not cheap, he adds. "The chemical industry would rather not have to do it, if only for purely economic reasons."

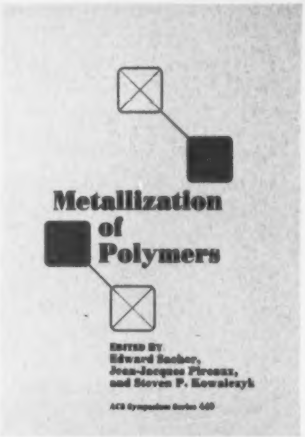
Indeed, suppliers are not immune to this controversy over ingredients. The challenge they face is to minimize or eliminate potentially harmful by-products, such as ethylene oxide, ethylene chlorohydrin, dioxane, and nitrosamine. Henkel's DeRosa notes there is a decided movement toward higher purity cosmetic ingredients. "It got hot in Europe first," he says.

Many companies, like ICI and Henkel, have modified their production processes to reduce significantly some of these by-products. But their elimination is often impossible. In the ethoxylation process, for example, which is commonly used in cosmetic ingredient chemistry, "you will always get some [ethylene oxide] and some 1,4-dioxane. There is no way around that," notes ICI's Chandler.

Even when these by-products are reduced to barely detectable levels, companies are still required to list them on labels on products sold in California as mandated under that state's Proposition 65, Chandler says. "We have to label just as suppliers that do nothing but ethoxylate and throw their product into drums without reducing levels of these by-products as we do," he laments.

Meanwhile, CTFA says it continues a broad-based campaign in opposition to the warning label requirements of Proposition 65 and similar proposed requirements in other states. Similar legislation has stalled in New York and Massachusetts.

The cosmetic and toiletries industry also must contend with efforts to ban or restrict aerosol propellant and alcohol formulations in consumer products. Last month, President Bush signed the first amendment to the federal Clean Air Act in 13 years. The act includes a plan to regulate "commercial and consumer products." It will require the U.S. Environmental Protection Agency to conduct a three- to four-year study of consumer products and determine their contribution to urban smog. After the study, EPA would target four product categories for regulation over an eight-year period. EPA could regulate those products that account for 80% of the volatile organic compounds (VOCs) contributed by all consumer prod-



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Edited By
Edward Sacher,
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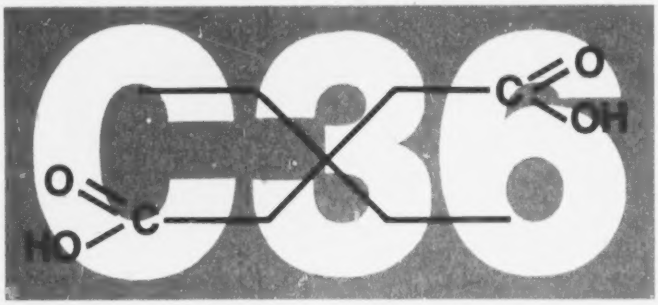

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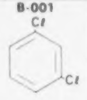
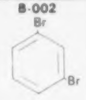
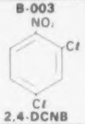
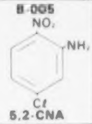
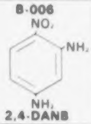
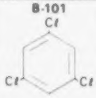
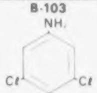
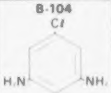
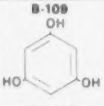
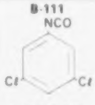
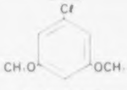
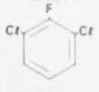
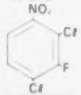
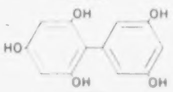
B-001  m-DCB	B-002  m-DBB	B-003  2,4-DCNB	B-005  5,2-CNA
B-006  2,4-DANB	B-101  1,3,5-TCB	B-103  3,5-DCA	B-104  3,5-DACB
B-109  1,3,5-THB	B-111  1,3,5-DCIB	B-118  5,1,3-CDMB	
B-201  2,6-DCFB	B-212  2,4,3-DCFNB	B-110  PHBP	

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ucts. No personal care products are named in the legislation, which does list paints, coatings, and solvents, notes CTFA.

Also last month, the California Air Resources Board's final hearing on the first round of consumer product regulations resulted in adoption of a substantially revised statewide standard that will allow the continued marketing in California of many consumer products in both aerosol and nonaerosol form. Previous versions would have banned many products, notes the Chemical Specialties Manufacturers Association.

At the Oct. 11 hearing, CSMA president Ralph Engel, representing the Consumer Products Coalition—CSMA, CTFA, and SDA—said: "Industry's goal has been to ensure effective air quality regulations in California that are technologically and commercially feasible as well as necessary. The regulations are to limit [VOC] emissions, not product VOC content, as well as to recognize the varying reactivity of different organic compounds so that there is no attempt to limit those that are not emitted."

Recognizing the potential impact of such legislation, companies like National Starch are adding to their product lines. Early this year, the company introduced its Amphomer LV71, a low-viscosity polymer for use in water-based hair spray solutions to achieve low VOC content. "As the whole trend away from VOC-based formulations continues, new resins will be continually introduced," says Nowak, adding that his firm has an active R&D program for such ingredients.

As controversy continues to swirl around the cosmetic and toiletries industry and its raw materials suppliers, it's no wonder that the group has gravitated toward personal care products that are perceived as natural. "The green issue is a real hot area right now, especially as companies market their ingredients and consumer products," notes Henkel's DeRosa. And National Starch's Nowak sums it up like this: "The major focus right now is environmental—giving the consumer a good, safe product that is environmentally friendly." □

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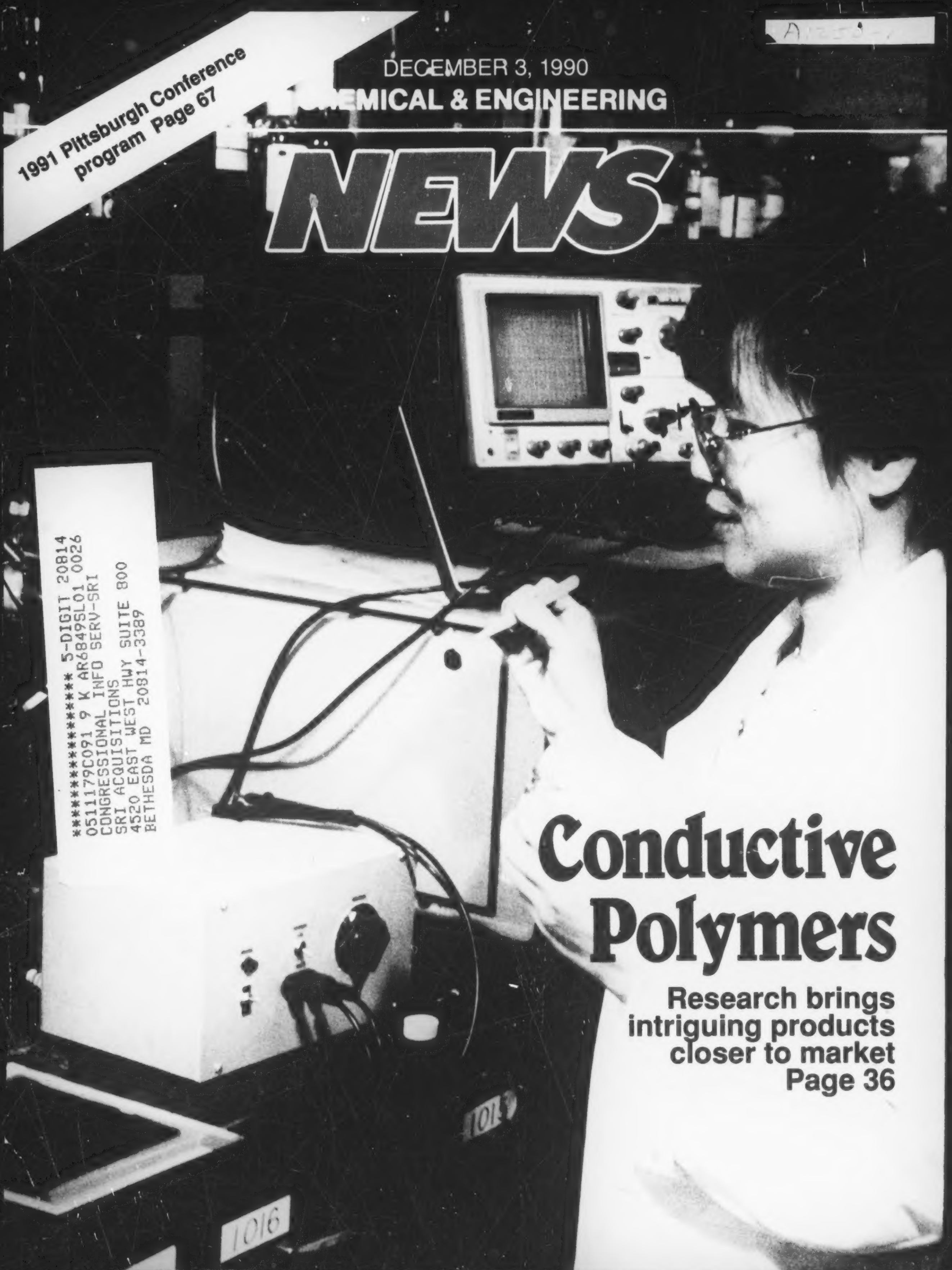
1991 Pittsburgh Conference
program Page 67

DECEMBER 3, 1990

CHEMICAL & ENGINEERING NEWS



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Conductive Polymers

Research brings
intriguing products
closer to market
Page 36

Volume 68, Number 49
CENEAR 68 (49) 1–84
ISSN 0009-2347

CHEMICAL & ENGINEERING
NEWS
DECEMBER 3, 1990

News of the Week

- **Scientists' panel assails Institute of Medicine report that recommends shifting scarce research grant funds to training and facilities.** Page 6
- **Researchers determine atomic structure of cell-surface glycoprotein that plays vital role in human HIV infection.** Page 7
- **New formaldehyde-from-methane direct oxidation method uses mild conditions and has oxygen conversion of 10% or less.** Page 7
- **OSHA begins hearings on major regulatory proposal regarding chemical process safety.** Page 8
- **U.S.-based SPI Pharmaceuticals and Yugoslavia's Galenika Pharmaceuticals announce merger, will be first such East-West union.** Page 8

Cover: Graduate student at Michigan State University tests conductive polymer

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Business

Drugs that treat disease by inactivating genetic process to prevent synthesis of disease-causing proteins are aim of young research firms. **Page 17**

Government

Massive budget bill holds grab bag of surprises, including extension of Superfund, provisions on pension plans. **Page 23**

Science/Technology

Advances in polarimetric detectors and microdialysis were among the highlights for the more than 3600 attendees at the 29th Eastern Analytical Symposium. **Page 29**

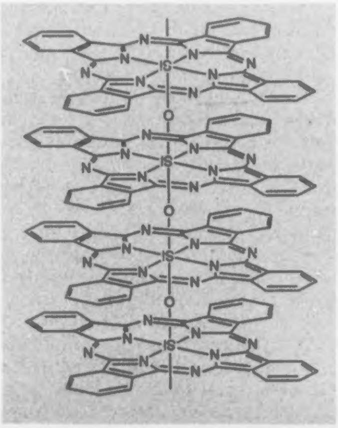
New lamp coating that blocks infrared light and reduces energy needed to keep filament hot enough to produce light is developed by General Electric researchers. **Page 35**

Books

Advice to scientists on the ins and outs, pros and cons of "Effective Expert Witnessing"; autobiographies of eminent organic chemists are also reviewed. **Page 55**

Meetings

1991 Pittsburgh Conference miniprogram includes listing of technical sessions, registration, other information. **Page 67**



Special Report

Excitement about practical uses for conductive polymers is high and some exotic products are closer to market, as research in the field continues to make steady progress. **Page 36**

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Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Catalytic antibodies

One of your articles (C&EN, May 28, page 26) described a tailor-made molecule: a catalytic antibody. Indeed, during the past decade, several articles describing the enzymatic activity discovered in various immunoglobulins, as well as synthetic proteins, have appeared in the literature. Having predicted this in 1974, I can only express my satisfaction with this development. The following describes how and why we had undertaken the studies that led to a most unexpected finding.

Increasing examples of engineered molecules comprised of immunoglobulin and of proteolytic enzyme halves, as well as of immunoglobulin molecules having proteolytic activity are quite interesting, but not surprising. In the early 1970s, during a study of homologies found among ancestrally unrelated proteins, we observed striking homologies between serine containing active site fragments of bovine trypsin as well as bovine chymotrypsin, the *S. Griseus* enzyme, and different Bence-Jones proteins, which we published in *Nature* [**251**, 353 (1974)]. We asked the question "Do immunoglobulins have proteolytic activity?" It is gratifying to see that these predictions are finally bearing fruit.

It makes eminent sense to have degradative activity(-ies) in immunoglobulin molecules, because this would increase their effectiveness. Natural selection can be expected to favor organisms that have these kinds of variants of immunoglobulins. Particularly when one considers an enzyme active site as a three-dimensional space, where certain functional groups are situated in a strategic way, one can easily accept that such activities could be manifest in many parts of proteins, or even nucleic acids.

Two ideas prompted the homology studies that led to the unexpected homologies discovered in 1974 and that have a bearing on this issue.

One, when small molecules such as RNase possess enzymatic activity, it is hard to believe that larger molecules could have only one activity or active site. In other words, if one were to search for biological activities in large molecules other than the ones for which they are known, one is likely to find some of them on these seemingly unlikely places. In endorphins, enkephalins, peptides A and B of cofibrin, and quite a few other cases, one finds examples of this idea. Whether they perform their biological functions while being a part of the larger molecule, or after being cleaved selectively by appropriate enzymes, is not important.

Two, it is pretty well established that all living organisms have stemmed from the first successful primordial cell. This ancestral cell, however, was obviously much simpler than the present-day organisms; namely, it had far fewer and smaller genes. During evolution, through gene duplications and mutations, etc., the number and complexity of these genes, and consequently of cellular proteins, have increased. However, we strongly believe that it should be possible to detect these original "segments" by studying the homologies among not only ancestrally related, but also unrelated, proteins. Fortunately for us, this expectation bore fruit.

Semih Erhan
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Department of Dental Medicine
Albert Einstein Medical Center, Philadelphia
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Career dedication

I felt a lot of sympathy for Ralph B. Nielsen's letter on graduate education. (C&EN, Sept. 10, page 3).

However, like so many others, he misses a point. This is, that the modern world is very highly competitive, and to get to the top in anything requires full-time dedication, which means giving up many things. Time off for any reason is likely to be fatal to really high career prospects.

Many women feel that other things are too important to be sacrificed for career prospects, and are consequently not willing to give the full-time dedication that is necessary for the highest success at anything. This I would claim is a major reason why women do not so often reach the highest positions. Moreover, in my experience I even think it is true that the most able women are more likely to think like this than some of the less able ones, which reduces the statistical chances of female success even more.

In my opinion, the women who will not give up other things for success in a career are absolutely right. What a terrible thing it would be if women were as deeply involved in the rat race as so many men are. What a lot of strain illness would be saved if more men thought that way too.

D. A. H. Taylor
Scarborough, Yorks, U.K.

BIOMEDICAL RESEARCH: Call for shifts in funding attacked

A panel of scientists representing the Federation of American Societies for Experimental Biology has rejected an Institute of Medicine report's recommendation to shift scarce National Institute of Health funds from research grants into training and facilities. The report's basic premise that research grants are receiving an inordinate share of funding at the expense of training is wrong, the FASEB group claims.

"If IOM's recommendations were carried out," says FASEB president Thomas S. Edgington, "they would have a strongly negative impact not only on the conduct of research but also on recruitment of new scientific investigators and would decrease the benefits of research to the public." But a member of the IOM committee that wrote the report says the FASEB group has misinterpreted it.

IOM's recommendations are relevant to chemical research: Almost one third of research funding for academic chemistry comes from NIH.

"We advocate ... a total increase of support of the enterprise as a whole," Edgington says. The IOM committee also would have liked to ask for more research funding, but its charge was how to best use available funds.

Grants would suffer if number of trainees increased

$ Millions	1990	2000	Difference
IOM recommendation[a]			
Research project grant support	$ 3,822	$ 3,640	−$182
Training support	$ 267	$ 379	+$112
FASEB impact analysis[b]			
Number of project grants[c]	20,463	19,487	−976
Number of trainees[d]	11,128	15,803	+4675

a Institute of Medicine proposal assuming no real growth in National Institutes of Health budget. b Analysis of IOM proposal carried out by panel of scientists from Federation of American Societies for Experimental Biology. c Assumes research project grants average $186,800. d Assumes costs of trainees average $24,000. **Sources:** IOM, FASEB

Edgington, professor of immunology at the Research Institute of Scripps Clinic, La Jolla, Calif., and six other scientists from the seven societies that make up FASEB met in late October to review the IOM report, "Funding Health Sciences Research: A Strategy to Restore Balance." The controversial report was presented in a symposium at the National Academy of Sciences in Washington, D.C., in September (C&EN, Oct. 8, page 22), but only was officially published in November.

IOM's panel on policies for allocating health sciences research funds spent two years putting its report together. The charge to the committee was to analyze the balance of funding for research projects, training, facilities, and equipment and suggest corrections if required. Under the ground rules set by IOM president Samuel O. Thier, the committee was not allowed to ask for more money for biomedical research.

The panel concluded that the share of available funds going to support training, construction, and equipment has been declining, with an increasing proportion going to research project grants—which bodes ill for the future. "We're eating our seed corn," committee chairman Floyd E. Bloom, head of the pharmacology department at Scripps Clinic, said at the September symposium.

"We must do something to begin to rectify what has occurred over the past 15 years," Bloom said. Therefore, the committee recommended shifting a small but significant portion of NIH's extramural funds from grant support into training and construction—even if NIH's budget does not increase over the next decade. "We did so even though we recognize there already is a growing problem in funding research," Bloom said.

The FASEB group contends the IOM report is based on a false premise and thus reaches incorrect conclusions. "We disagree with the basic premise of imbalance," Edgington says. "Training has not decreased."

According to the FASEB analysis, even though the proportion of funds earmarked for trainees has slipped, individual research grants have adopted much of the support for training. Edgington suggested the IOM panel may have overlooked that subtlety because the panel was made up mostly of research administrators and social scientists and had few "working scientists."

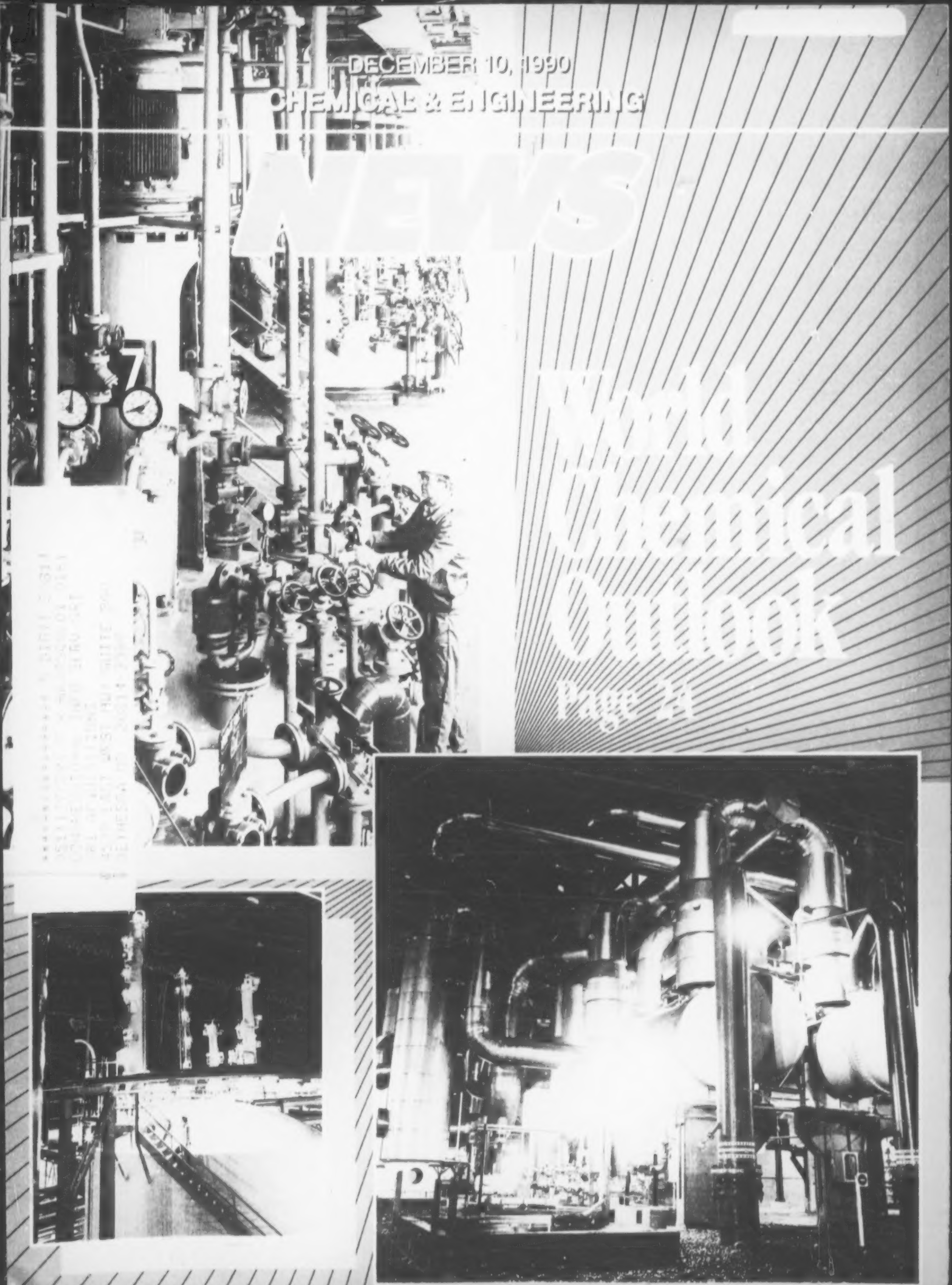
"That's preposterous," says Ronald C. Breslow, professor of chemistry at Columbia University and one of the working scientists on the IOM committee. "Of course we know trainees are supported by research grants. We're not chumps. We decided that was not the best way to do it."

The panel concluded that training grants and fellowships are better ways to educate researchers. "Supporting training through research grants ties training too much to the success of the research adviser," Breslow says. "Giving money to the student rather than the sponsor changes their relationship. Trainees can then work on their own projects rather than being a sort of employee. It's more encouraging to the student to be told 'You are a winner' rather than 'Just go beg for support.'"

Pamela Zurer

DECEMBER 10, 1990

CHEMICAL & ENGINEERING NEWS



World Chemical Outlook

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CHEMICAL & ENGINEERING
NEWS
DECEMBER 10, 1990

Volume 68, Number 50
CENEAR 68 (50) 1–60
ISSN 0009-2347

News of the Week

- **CMA survey shows chemical makers upbeat about 1991 despite softening of U.S. economy and uncertainties generated by Persian Gulf crisis.** Page 6
- **Progress in domestic and international efforts to map the human genome was described at meeting of genome project officials and advisers at NIH last week.** Page 6
- **NSF's Presidential Young Investigator awards program may face cuts of 50% or more, with awards going to more experienced researchers.** Page 7
- **ACS Board, meeting in Washington, D.C., reelects Joseph A. Dixon as chairman, takes action on several matters.** Page 7
- **Arco Chemical president and chief executive officer Harold A. Sorgenti has unexpectedly announced his retirement, effective next June, and will be succeeded by Alan R. Hirsig.** Page 8

Business

Prices and demand for aromatics will likely weaken after unusual price upswing earlier this year as a result of the Middle East crisis. **Page 11**

Government

Although federal funding of chemical R&D went up during 1980s, increases for chemistry have not kept up with those for other disciplines in recent years. **Page 14**

Science Policy

Panel studying U.S.-Japan relations for the 21st century suggests broad and varied ways to improve, foster collaboration in science and technology. **Page 16**

Science/Technology

Wholly inorganic synthesis of aluminophosphate molecular sieves achieved by Georgia Tech researchers. **Page 19**

New research consortium forms to use "world's fastest computer," an Intel supercomputer to be installed at Caltech. **Page 20**

Internal motion of protein domains is probed by supercomputer-based method developed by Connecticut chemists. **Page 20**

World Chemical Outlook

Chemical companies throughout the world are concerned that easing demand for their products, coupled with rising capacity, will undercut prices at the same time that petrochemical raw material costs escalate as a result of tension in the Mideast. **Page 24**

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Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director
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PUBLISHING BOARD: Jean'ne M. Shreeve (*Chairman*); *Board of Directors Chairman*: Joseph A. Dixon; *President*: Paul G. Gassman; Richard L. Deming; William P. Jencks; Gary J. Long; and Louis D. Quin

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Subscription Rates 1990. Printed editions: nonmembers U.S. 1 yr. $60, 2 yr. $108, outside U.S. 1 yr. $93, 2 yr. $174. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $9.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

CHEMICAL SAFETY

Synthesis of nopinone

As mentioned by Patrick M. Gordon in his letter (C&EN, Aug. 6, page 2), we also had problems trying to synthesize (+) nopinone.

After running the reaction successfully many times, in small scale, using acetic acid and sodium iodide or acetic acid and zinc for the decomposition of the ozonide, we decided to scale up this reaction.

Four samples of 45 millimoles of β-pinene were ozonized for two hours in CH_2Cl_2/CH_3OH. The four samples were combined and cooled in a water/ice bath, and acetic acid and zinc were added in order to decompose the ozonide.

The solution was concentrated in a rotavap and stored in a freezer for further workup.

When this sample was let to warm up at room temperature, a violent explosion occurred. Fortunately, nobody in our lab was injured.

José Tércio B. Ferreira
University of São Carlos
Brazil

Funding for biomedical research

The recommendations of the Institute of Medicine panel (C&EN, Oct. 8, page 22) regarding the disposition of funding for biomedical research represents a major step backward. While I see much merit in establishing a sliding scale for the funding of investigator-initiated grants, their recommendation to emphasize support for training grants and facilities construction to the detriment of individual research grants smacks of a campaign to provide bicycles to fish. Without adequate support for individual research projects, it is simply not possible to train individuals properly for careers in scientific research. Furthermore, we will continue to send the demoralizing message that the prospects for successful research careers in this nation are slim. This will certainly have a negative impact on the pool of potential trainees, exacerbating an already serious manpower shortage.

Given limited total funding for biomedical research, I see no reason for change in the current mechanism for facility construction (which is largely dependent upon fund-raising by individual institutions). I also perceive great danger in the centralization of research effort through the proliferation of research centers. In the long run, "big science" is doomed without a stable infrastructure provided by investigator-initiated research and training.

It seems significant that relatively few M.D.s become full-time researchers. Thus, the impact of the regressive funding policies recommended by the Institute of Medicine would have little effect on its own constituency.

John M. Schwab
Associate Professor of Medicinal Chemistry
Purdue University

What is a chemical?

Are we chemists partly to blame for the public's lack of understanding of chemicals and the poor public image that chemistry has? Poor science education and poor communication between chemists and the public are certainly contributing factors. The problem of communication is not made easier by the fact that nobody really knows what a chemical is.

The general public thinks of chemicals as unpleasant, smelly, and poisonous substances that should not be allowed to enter the atmosphere or our water supplies even in the most minute amounts. Most people do not think of water or oxygen as chemicals. Food additives are regarded as chemicals, but substances occurring naturally in food are not thought of as chemicals. Some people consider synthetic vitamin C to be a chemical, but not the vitamin C found in lemon juice, or the vitamin C in a bottle labeled "natural" vitamin C.

Complete confusion reigns as to what is meant by a chemical, as is illustrated by an item in Newscripts (C&EN, July 16, page 56), which quoted a press report that "trees would be sprayed this week due to an infestation of gypsy moths and aphids. The material to be applied is environmentally safe since it is an organic compound, not a chemical." We might at first be tempted to smile at the ignorance of the reporter, but we should be alarmed by this typical misunderstanding.

If we search among chemistry textbooks, nowhere can we find a definition of a chemical. If we consult a dictionary we find statements such as, "A substance obtained by or used in a chemical process." Chemists often use the word in the sense of a substance produced by the chemical industry. In this sense, sulfuric

Prices and Demand for Aromatics Reverse Earlier Gains

Early price runup not likely to be long-term plus for aromatics; prices and demand freeze as potential stalemate in Middle East looms

Bruce F. Greek, C&EN Houston

Pricing and demand for aromatics have turned from strong to neutral and likely will further weaken if a stalemate develops in the Middle East situation this winter. Long term, the demand pressure and sudden high prices for aromatics could become only a blip on the curve of the statistics.

The runup in crude oil and fuel product prices has caused similar price increases for the major-volume aromatics—benzene, toluene, and mixed xylenes. Demand for these aromatics rose when hoarding began as it did for most large-volume organic chemicals. For some, selling prices took off, rising more than prices for gasoline (which competes with chemical uses for all of these aromatics).

The crisis in the Persian Gulf has changed what would have been a down year for aromatics demand and a shaky year for prices and profits. Next year's outlook is so uncertain that few industry observers will forecast demand for aromatics without qualifications regarding the various possible developments in the world situation. In the absence of a shooting war, views generally are for weak demand during the first half of 1991, made slightly worse by some inventory reduction.

Inventory reduction is now under way, according to industry sources. The price decline for benzene suggests that the opportunity for a timely inventory reduction has passed. During the initial runup, spot benzene prices had exceeded the contract price. But by November, when the contract price was $2.00 per gal, this had turned around.

During November, the spot price declined to $1.45 to $1.50 per gal by the last week of the month, says Hugh S. Pylant, a senior consultant at Pace Consultants. In late November, the contract price for benzene to be sold in December had not generally been set by sellers. However, it's widely speculated that the contract price will relate more closely to the spot price, as it does when no major event affects demand.

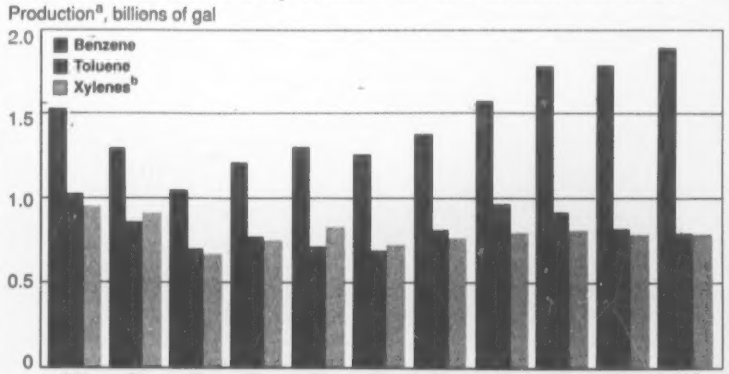
In calmer business times, the price of benzene depends on chemical demand, compared with its value in gasoline, and on the cost of extracting it. The value of toluene, which influences decisions to operate units to hydrodealkylate toluene to make benzene, has minor influence on benzene prices.

Most benzene, toluene, and xylenes consumed in various derivatives come from catalytic reformate, which is made in refineries from suitable crude oil fractions containing precursors of these aromatics. If a chemical need exists, then the aromatics are extracted from the reformate, which otherwise would be blended into gasoline because of its high octane value. Additional quantities of aromatics are extracted from pyrolysis gasoline, a coproduct of ethylene made in steam crackers. Small quantities also are obtained from coking coal. The aromatics are separated in refineries and sold or used in the refinery operations, depending on the better economics.

Because of the high benzene demand in chemical uses little of the benzene extracted and purified is blended back into gasoline. However, due to their high blending octane values (100 to 110 and 95 to 115, respectively), toluene and xylenes may be returned to the pool of components blended in making finished gasoline.

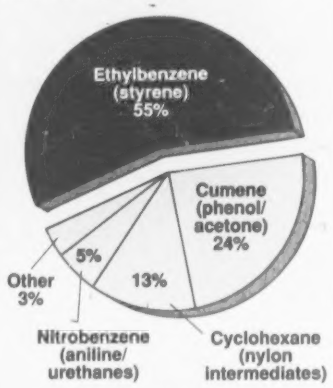
Benzene demand growth roughly

Growth in benzene output exceeds that of other aromatics



a All sources as reported. b Includes some ethylbenzene. c Preliminary. d Forecast. **Sources:** U.S. International Trade Commission, National Petroleum Refiners Association, C&EN estimates

Styrene production a top use for benzene



1990 consumption = 1.9 billion gal

Source: C&EN estimates

follows growth in the economy as it affects demand for durable goods. Benzene production for 1990, however, will total about 1.9 billion gal, says Pylant, up more than 5% over the 1.8 billion gal estimated to have been produced in 1989. However, this growth has been stimulated by some stockpiling during the past four months.

The largest chemical use of benzene is in making ethylbenzene, nearly all of which becomes styrene. Most of the major uses of styrene in polymers are mature products. Growth of the derivatives and of benzene, therefore, will be low, probably about 3% annually, if no special stimulus occurs to spur inventory building. Imports now closely match exports of styrene as capacity comes on stream in other parts of the world. Current styrene supply remains tight because an accident stopped output at Arco Chemical's Channelview, Tex., complex and because maintenance shutdowns and mechanical problems have interrupted other companies' output. Following the rise in benzene prices this summer and fall, styrene prices rose but now have settled back and are holding at 50 to 55 cents per lb.

Cumene and cyclohexane follow ethylbenzene as the largest uses for benzene. The major end products of these derivatives—phenolic and nylon resins—go mainly into houses and commercial buildings. The current weakness in real estate has reduced construction, bringing anticipated lower demand for these uses. Temporarily, therefore, both of these products are expected to have only modest growth in their demand for benzene. Other significant uses of benzene, such as nitrobenzene, alkylbenzenes used as surfactants, and chlorobenzenes, show low growth and will have little impact on any benzene improvement.

For toluene, about 90% of the product produced is never recovered from its sources—reformate, pyrolysis gasoline, and coal tar—since it is used in gasoline production. Of the remainder, more than half is dealkylated to make benzene. Various formulas exist to determine whether toluene costs sufficiently less than benzene so that a dealkylation unit can be profitably operated. In late November, nitration-grade toluene (needed or preferred by many dealkylation plant operators) cost about $1.10 per gal, sufficiently below the price of benzene to make toluene dealkylation profitable.

Part of the reason for the relatively low price for toluene in November stems from a decline in demand for high-octane components for gasoline. The increase in gasoline prices has reduced demand for premium gasoline and, thus, reduced demand for toluene as a blending component. Until motorists decide again that premium gasoline is worth its cost, toluene prices are expected to hold, as inventories are reduced and production is limited.

Similar to toluene, roughly 90% of mixed xylenes produced are estimated to be unrecovered from their sources—also reformate, pyrolysis gasoline, and coal-tar, plus disproportionation of toluene. The recovered mixed xylenes include the three isomers—ortho, para, and meta—along with varying amounts of ethylbenzene. Separation of these materials is difficult and expensive, compared with other petroleum processes. The degree of separation varies widely, with the unwanted components being returned to the gasoline pool. Some of the mixed xylenes are sold as solvents, a use expected to continue to decline.

Normally, *o*-xylene is separated first by distillation. Almost all purified *o*-xylene is converted to phthalic anhydride that is used to make plasticizers for polyvinyl chloride and other plastics. Small amounts go into such diverse end products as herbicides and lube oil additives.

In November, *o*-xylene cost as much as *p*-xylene, or slightly less than 30 cents per lb, which is an unusual situation compared with the past when *o*-xylene cost 20 to 40% less than *p*-xylene. The reason seems to be a slow decline in *o*-xylene capacity during the 1980s with an increase in production of phthalic anhydride, says Teresa A. Acosta, vice president of DeWitt & Co. At the same time, *o*-xylene further replaced naphthalene as the raw material. Consequently, less than 10% of phthalic anhydride now is made from naphthalene.

The decline in *o*-xylene capacity also has affected the export market. In 1980, almost half of *o*-xylene output was exported. At mid-decade, exports declined precipitously and imports rose to exceed exports. A reversal has occurred as imports have declined owing to increased demand elsewhere in the world and to the weakening of the U.S. dollar.

Output of *p*-xylene in the U.S. has been on hold at about 5.5 billion lb during the past three years, largely because of capacity limitations. New capacity to make *p*-xylene in the U.S. has not been built because exports are expected to decline as new capacity is put in place in Asia and because imports of garments made of polyester are rising amid a shift toward more use of cotton.

Almost all *p*-xylene is converted to dimethyl terephthalate (DMT) or into purified terephthalic acid (PTA). DMT and PTA are made into polyester fibers and film, polyethylene terephthalate for bottles, or polybutene terephthalate for engineering plastics. The strong growth in bottle resins stopped in 1989 when prices were increased and the resins failed to capture markets for smaller sized bottles. As pricing settles out, the growth in bottle resins will continue to exceed growth for fibers. Exports, long expected to decline, are holding up, causing continuing pressure on capacity. □

Since '85 Chemistry Has Lost Ground In Race for Federal R&D Funds

However, academic chemistry held its own in 1980–88, growing 5.0% yearly in real terms compared with 3.7% for all federal academic support

Janice R. Long, C&EN Washington

Some questions: How well has academic chemical research fared since 1980? Is it getting more or less federal support than it was then? Has chemistry fared as well as other disciplines when it comes to obtaining federal research monies?

Some answers: The federal government spent about $4.1 billion on academic R&D activities in fiscal 1980. By fiscal 1988 that number had grown to $8.2 billion. Those figures represent an average annual growth rate of 9.1%. During the same period, federal funding of academic chemical research activities had grown from just under $190 million to over $400 million, an average annual growth rate of 9.8%. However, since 1985 increases for chemistry have not kept up with those experienced by other fields of research.

Those answers are found in a new report, "Federal Funding of Academic Chemistry Research FY 1980–FY 1988," published by the American Chemical Society's department of government relations and science policy. The report was prepared, at the request of ACS president Paul G. Gassman, by former ACS science policy fellow Patricia A. Cunniff, professor of chemistry and associate director of the science and technology center at Prince George's Community College, Largo, Md.

Chemistry accounted for 4.6% of total federal academic R&D funding in fiscal 1980. That share rose to a high of 5.2% in fiscal years 1984 and 1985 and then fell back to 4.9% in fiscal 1988. Physics' share of the federal pie in 1980 was 6.8%, hitting a high of 7.6% in 1986, and falling back to 7.0% in 1988. During the eight fiscal years covered in the report, federal funding for academic R&D in the area of life sciences never fell below 51% of the total and never rose above 53%, while engineering funding hovered between 14.5 and 15% of the total.

The picture is bleaker for basic academic research in chemistry. The real average annual increase in federal obligations for basic, academic chemistry research between fiscal 1980 and 1988 was 3.5%; the increase for all disciplines was 4.9%. And funding for basic chemical research actually declined 0.1% annually in real terms between fiscal 1985 and 1988.

Some ground rules must be observed in interpreting the report. One is that it adheres to the federal government's definition of chemistry. To wit, chemistry is a physical science that includes inorganic, organometallic, organic, and physical chemistry. As a consequence of this definition, the figures for chemistry quoted in the report do not include funding for such fields as biochemistry or geochemistry. They also do not include funding for chemical engineering R&D.

Second, R&D as reported on the federal surveys on which most of the report is based includes all research activities, both basic and applied, and all development activities supported at colleges and universities. R&D also includes such research equipment as computers, software, and spectrophotometers.

The report finds that, as a discipline within the university system, chemistry is more dependent upon federal monies than the life sciences and engineering but less dependent than physics. In 1988, academic chemistry received 71.2% of its R&D funding from federal sources, compared with the life sciences' 59.6%, engineering's 58.8%, and physics' 79%. Chemical engineering R&D is

Growth in federal support for academic chemistry R&D lags that for all R&D

										Annual change	
$ Millions, constant 1988	1988	1987	1986	1985	1984	1983	1982	1981	1980	1985–88	1980–85
Life sciences	$4311.1	3940.2	3708.4	3477.1	3182.3	3021.5	3047.2	3089.2	3007.6	7.4%	2.4%
Engineering	1224.6	1140.8	1036.2	944.8	877.5	863.7	849.1	865.0	856.5	9.0	2.0
Physics	573.3	543.6	540.6	493.3	437.4	399.9	373.0	403.3	402.1	5.1	4.2
Chemistry	403.0	376.0	358.8	341.4	314.2	289.2	280.5	283.0	272.4	5.7	4.6
Other[a]	1652.8	1544.3	1475.4	1353.1	1283.0	1241.6	1231.5	1313.5	1342.2	6.9	0.8%
TOTAL	**$8164.8**	**$7544.9**	**$7119.4**	**$6609.7**	**$6094.4**	**$5815.9**	**$5781.3**	**$5954.0**	**$5880.8**	**7.5%**	**2.1%**

Note: Fiscal years. a Includes mathematical, computer, environmental, and social sciences.

Chemistry proposals stand better chance getting NIH funding . . .

	Number of grant applications			Success rate
	Requested	Recommended	Awarded	
1980	699	618	295	41.8%
1981	745	678	274	36.8
1982	941	859	333	35.1
1983	730	693	275	37.5
1984	650	613	240	36.8
1985	803	766	353	43.2
1986	755	726	329	43.5
1987	645	621	259	40.0
1988	780	762	291	37.2

. . . than funding from NSF's chemistry division . . .

	Mean award size[a]		Mean duration in years	Success rate
	$ Current	$ Constant		
1980	$62,417	$89,662	2.4	30.4%
1981	68,619	89,616	2.4	41.0
1982	71,216	86,691	2.4	40.8
1983	75,686	88,394	2.6	40.8
1984	79,720	89,701	2.5	35.3
1985	84,261	91,971	2.7	35.9
1986	86,268	91,651	2.7	35.4
1987	86,173	88,715	2.5	30.2
1988	86,340	86,340	2.5	26.6
1989	84,590	81,477	2.5	34.0

. . . or from Air Force's Office of Scientific Research

$ Millions	Contract budget	Share to chemistry departments	Proposals received	Proposals funded	Success rate
1980	$ 6.3	$ 4.7	263	36	13.7%
1981	6.5	4.9	272	43	15.8
1982	7.6	5.7	322	74	23.0
1983	8.1	6.1	336	64	19.0
1984	8.3	6.2	371	69	18.6
1985	13.9	10.4	320	57	17.8
1986	13.8	10.4	331	23	6.9
1987	13.6	10.2	294	10	3.4
1988	16.0	12.0	289	14	4.8

Note: All years are fiscal years beginning Oct. 1. [a] Includes all awards between $2000 and $1 million by chemistry division. **Source:** American Chemical Society, "Federal Funding of Academic Chemistry Research FY1980–FY1988"

least dependent, getting only 51.3% of its support from federal sources.

As to which parts of the government fund academic chemistry, the answer is no surprise. Four federal agencies—the National Science Foundation, the National Institutes of Health, the Department of Defense, and the Department of Energy—provided over 92% of federal monies obligated to universities and colleges for chemical R&D in fiscal 1988.

NSF led the list, providing $111.6 million, or 37% of academic chemistry funding in 1988, over 96% of which went for basic research. Of that total, the chemistry division supplied $93.7 million and the division of materials research $22.47 million.

However, the omens are not good. The report points out that in constant dollars, NSF funding for academic chemistry grew at an average annual rate of 5.1% between fiscal 1980 and 1985. It then fell 1.8% per year between fiscal 1985 and 1988.

This trend is reflected in the chemistry division's budget, which rose steadily throughout the first half of the 1980s but stagnated in the second half, actually declining when corrected for inflation. The number of grants awarded by the division did rise from over 700 new and competing grants in fiscal 1980 to 1048 in fiscal 1988. However, the average annual grant size decreased nearly 10% in real terms during that period.

According to the report, the overall success rate for proposals submitted to NSF's chemistry division started the 1980s at 30.4%, hit a low of 26.6% in 1988, and climbed back to 34.0% in 1989. The success rate for NSF as a whole declined from 41.8% in 1980 to 37.2% in 1988.

Altogether, approximately 83% of the chemistry division's budget supports individual investigators. For NSF as a whole, individual investigator awards dropped from 68% of the research and related activities account in fiscal 1980 to 60% in fiscal 1988.

According to NSF surveys, NIH, primarily through the National Institute of General Medical Sciences, provided almost 30%, or $89.3 million, of federal funding for academic chemical research in fiscal 1988, up from a total of $74.4 million in fiscal 1986. NIH thinks it did a lot better than that. According to figures supplied for the report by the division of research grants special projects office, NIH awarded 1153 research grants worth $134.9 million to academic chemistry departments in fiscal 1986. In 1988, according to NIH, chemistry research grants (defined to include both chemistry and the structural chemistry of biopolymers) totaled $139 million.

According to the report, an NIH study for fiscal 1985 and 1986 found that the success rate for NIH grants submitted by chemistry departments was higher than the average for all departments. The chemistry department success rate for 1985 was 43.2%, compared with 37.2% for all departments, and 43.5% in 1986, compared with 35.8%. However, research grant support for chemistry is growing more slowly than is grant support overall.

DOD provided $41.3 million for academic chemical research in fiscal 1988, compared with $17.4 million in fiscal 1980. However, that 9.7% average annual rate of growth is most probably over for the near future. Army funding of academic chemical research has been declining steadily since 1986 and the rest of DOD is now treading the same downward path.

The fourth major funding agency, DOE, provided nearly $34 million for academic chemical research, both basic and applied, in fiscal 1988, compared with just under $15 million in fiscal 1980. In fact, at DOE the inflation-adjusted average annual growth rate for academic chemistry research during the period covered by the report, 5.8%, is higher than the 2.2% average annual growth rate in all academic disciplines funded by DOE. This occurred, the report notes, despite the fact that funding for the chemical sciences "grew at a constrained 2.9% per year in real terms" during the same period.

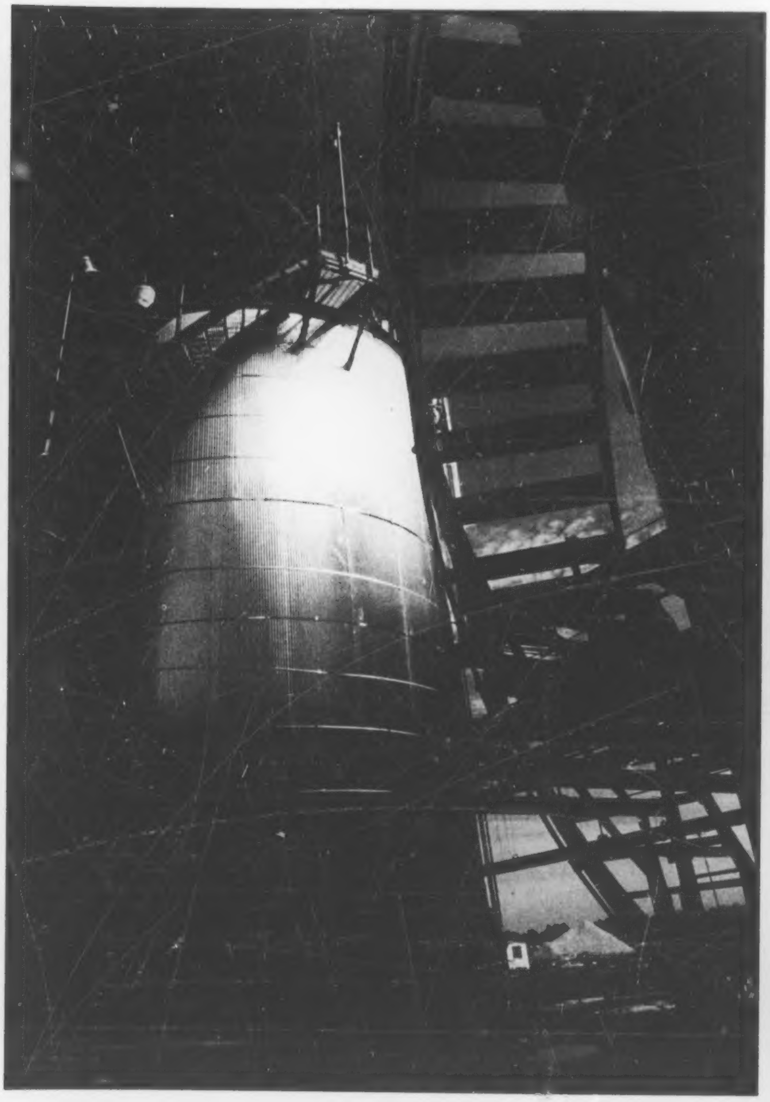
The ACS report concludes on a somber note saying that "While chemistry experienced growth between fiscal 1980 and 1988, based on analyses of both obligation data and expenditure data, the slowing down of this growth after 1985 warrants monitoring." □

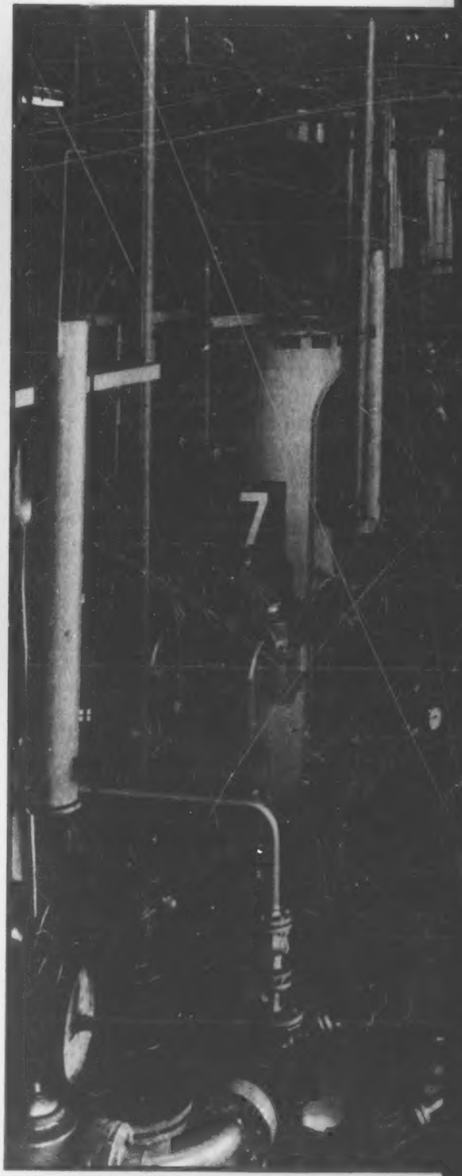
World Chemical Outlook

The recession that the majority of business analysts agree is now under way in North America—or at least will be by the start of 1991—may well be one of the best heralded downturns on record. But that will not make it any easier to weather for the chemical industry—especially if, as seems likely in an increasingly global economy, the slump spreads worldwide.

Already chemical producers worldwide are smarting under the shock of sharply higher costs for their key raw material, petroleum. If consumption of chemicals were high and growing, producers probably could pass the rise in their operating expenses through to their customers. In fact, they have been doing just that to some degree.

But as overall economic growth stalls, falling demand is severely limiting their ability to control prices. And it doesn't help that a number of big new petrochemical plants, planned during the period of heady growth during the late 1980s, now are coming on stream, adding potentially unneeded and possibly in-





digestible increments to available supplies.

The last time the chemical industry went through a cost/price wringer—in the early 1980s—it emerged much changed following a wave of reorganization and restructuring that was undertaken to pare costs and trim excess capacity. That effort seemed to pay off during the heated prosperity of the late 1980s, when chemical companies reaped bountiful profits. But the real effectiveness of their tightened operations will be put to a much more telling test during the chillier economic climate now in prospect.

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United States

Costs up, demand slack: pain for chemical firms

With consumption curtailed in several key markets, U.S. chemical industry is finding profitability under pressure

David M. Kiefer
C&EN Washington

With demand depressed in several key markets, consumption of chemicals is easing. Consequently, output of chemicals also is slowing—just as several big new plants have come, or are about to come, on stream. At the same time, turmoil and tension in the Middle East have triggered a sharp surge in the cost of crude oil, one of the chemical industry's most important raw materials.

Clearly, then, U.S. chemical producers are going to have to belt up for a rough ride for the next few months, if not longer. While sluggish demand is putting a lid on selling prices, rising costs will be eroding profits.

Recent statistics give only a hint of potential problems, to be sure. Production of chemicals and synthetic materials has edged moderately lower since its recent peak last spring; now it's probably running about 1% below the level of late last year. And it probably would be off even further were it not for customers' distorting demand during the past few months by building up their inventories in anticipation of higher prices. For all of 1990, output will be essentially unchanged from 1989, after being ahead by nearly 1% during this year's first half.

Output for the chemical industry as a whole, meanwhile, has slipped to about 81% of capacity, according to Federal Reserve Board data. That's down from a peak of 87% in 1988. Even so, capacity utilization is still comfortably higher now than eight years ago, when it fell as low as 70%.

Selling prices of chemicals by last summer had been drifting downward for more than a year. They were under pressure from sluggish growth in the overall U.S. economy and customers' hesitancy to place orders pending the expected startup of big increments in plant capacity. Polyethylene capacity in North America, for example, will be nearly 20% higher than now by the end of 1991.

Since August, however, chemical prices have ballooned—more than 5% since a year ago, on average, for industrial chemicals—as oil prices doubled and producers tried to pass on to their customers, as much as possible, the sudden rise in the cost of their hydrocarbon feedstocks, natural gas as well as petroleum, on the heels of the military crisis in the Persian Gulf. Nevertheless, the current rise in selling prices has only partially offset higher raw material expenses. For all of 1990, though, prices of industrial chemicals will average about 1% less than last year.

The result has been a sharp fall in the earnings of basic chemical producers. Net income for companies making industrial chemicals and synthetic materials was down about 25% from the year before during the first nine months of 1990. This year's fourth quarter will not stack up quite that unfavorably with 1989's like quarter, but only because profits already were deeply depressed then. For all of 1990, though, the industry probably will turn in earnings about 20% under those of the year before.

Next year, with the nation's economic climate expected to be much more chilly than during the past few years, the chemical industry may find itself put to the test. Much depends, of course, on just how stressful business conditions actually are in the next few months. Clearly, growth has slowed markedly in the overall U.S. economy. Nevertheless, government statistics still do not offer conclusive evidence that the unprecedentedly long (in peacetime) expansion of the past eight years has finally ended. Gross national product (after factoring out inflation) continued to grow—at a better-than-anticipated annual rate of 1.7%—during 1990's third quarter. That's up from an anemic 0.4% rate in the second quarter and was about on par with growth in the first quarter.

Economists, as usual, are not speaking with one voice in assessing the current business scene. But the consensus among forecasts now points strongly to a recession in U.S. business by the beginning of next year—if it is not now already here.

Most economists also are predicting that the impending recession will be relatively shallow and short-lived—lasting, most likely, no more than six to nine months and pulling real GNP down less than 2%.

By next autumn, then, if such predictions are on the mark (and assuming the shock of the Mideast crisis has eased), business will be once more on the upswing. That would make the 1991 recession one of the least painful on record—certainly much less so, for example, than the most recent previous recession in 1981 and 1982.

But it is not hard to find dissenters to this consensus view. On one end of the scale are a declining number of optimists who continue to argue that even though economic growth is lagging, the slowdown will not fall into actual recession. On the other end are numerous pessimists who contend that the nation's economic structure is much more rickety than is generally recognized.

They warn that the country should gird itself for a long, severe decline, one akin to the 16-month slump of 1981–82, which was probably the worst the U.S. has suffered through since the 1930s. And they buttress their concern by pointing to the present heavy burden of outstanding public and private debt, the intractable federal budget deficit, the financial fragility of the U.S. banking system, tight credit in the wake of the savings-and-loan scandals, and the economic cost and inflationary consequences of high and volatile energy prices. All these factors might well make recovery uncertain, if not unlikely, any time before the end of 1991, if even then.

Whatever the prognosis for the economy as a whole, it is certain that several of the chemical industry's most vital markets—notably construction and motor vehicle manufacturing—are already in distinct decline.

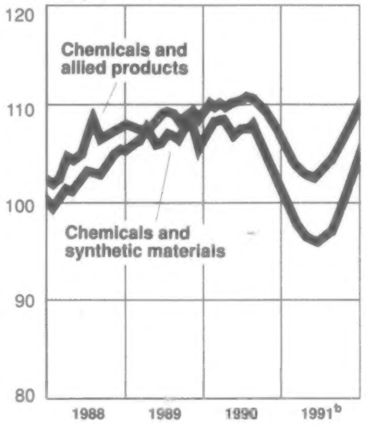
Probably no sector of the economy has been in more serious trouble than homebuilding. The number of new housing starts has been declining each month since last January; by October it had hit the lowest level, at an annual rate of only a little over 1 million, for any month in more than eight years. Only about 1.2 million housing units are likely to be started in all of 1990, 13% fewer than the year before and down a third from four years ago.

About the only good news in the housing business is that it seems unlikely that it can sink much lower. Next year, housing starts are generally expected to fall a bit more, to be sure, dropping to somewhere between 1.0 and 1.1 million. But most analysts think that will be the bottom and that homebuilding really has nowhere to go but up. Housing starts have not been lower than 1 million, after all, in over 30 years.

But if housing looks bad, commercial construction—stores and office building, for example—is much the worse. Office vacancy rates are high—near 20%—nationwide and retail merchants have been plagued by overexpansion. As a result, the value of commercial building contracts likely will plummet 8 to 10% this year and fall at least half as far again in 1991.

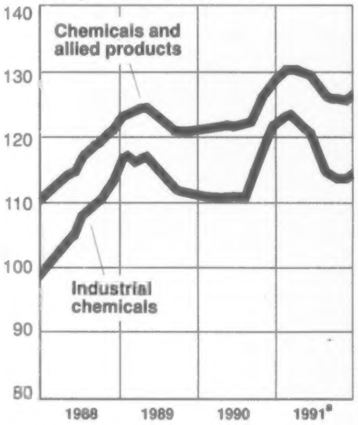
The automobile industry likewise has been a weakening market for chemical products. Lower total car and truck sales in the U.S. this year are forcing cutbacks in car production as well. Output of new cars will probably drop at least 10 to 11% below the 1989 total, while truck production is likely to drop 5%. And next year is likely to bring further declines, with total vehicle output off as much as 10%.

Other consumer products that are important markets for chemicals are hurting, as well. Analysts expect shipments of all electrical appliances to ease 3 to 5% this year and proba-



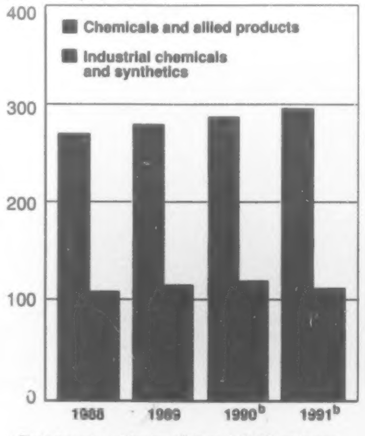
Slackening demand is trimming chemical output . . .

a Seasonally adjusted. b C&EN estimates.
Source: Federal Reserve Board



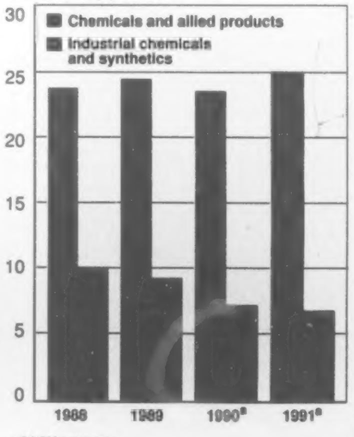
. . . and after a brief uptick, prices will soften . . .

a C&EN estimates.
Source: Bureau of Labor Statistics



. . . crimping chemical producers' sales . . .

a Excludes sales of foreign affiliates. b C&EN estimates.
Source: Bureau of the Census



. . . and putting severe pressure on profits

a C&EN estimates.
Source: Bureau of the Census

bly show a similar drop next year. Meanwhile, textile production has been, at best, stagnant and probably will decline 2 to 3% in 1991. Production of furniture is in similar straits.

All of which probably spells big trouble for producers of big-volume chemicals, plastics, and man-made fibers during the next few months. The excessive inventory hedging of the past few months will rob sales from the first half of 1991. For the year as a whole, weaker demand is likely to cut production 7 to 8% below 1990's level. Looking across the economic valley (assuming it is indeed a shallow one), output of industrial chemicals and synthetic materials will be no higher by year end 1991 than it was a year ago; capacity utilization will be appreciably lower.

One positive factor for U.S. chemical firms recently has been their foreign trade. With the U.S. dollar depressed relative to currencies in the industry's major overseas markets in Europe and the Far East, U.S.-produced chemicals have been very cost competitive. In addition, U.S. producers of petrochemicals are less affected by higher oil prices because for feedstocks they (and their Canadian counterparts) rely more on ethane and propane from natural gas and less on petroleum-derived naphtha than their European and Japanese competitors. North America thus can make petrochemicals and many plastics more cheaply than just about anywhere else.

But economic growth, which this year has generally been more buoyant in many places abroad than in the U.S., is expected to slacken in Europe and Japan as well in 1991. In several overseas markets, too, local production is displacing imported materials. Consequently, U.S. exports of chemicals, up a mere 4% this year, may not grow at all in 1991.

In this business climate, makers of commodity chemicals and plastics will be hard pressed to hold their recent price levels. By next spring, selling prices of industrial chemicals and plastics are likely to be declining again, although prices for 1991 as a whole probably will average 4 to 5% higher than this year. That will be nowhere enough, though, to offset higher raw material costs.

As a result, profits for producers of basic chemicals probably will take another hit next year. The drop, year-to-year, though, is not likely to be quite so severe as this year.

The broad chemicals and allied products industry includes, of course, many firms that do not market commodity chemicals or plastics. Among these are a diverse assortment of specialty chemical makers, and for them the outlook is markedly brighter. Their raw material costs are tied much less directly to hydrocarbon prices and their selling prices are less at the mercy of classic supply-and-demand constraints. Many of them, too, service relatively recessionproof noncyclical customers.

Even more of a special case is that major segment of the industry that produces pharmaceuticals. Its relatively recessionproof sales, bolstered by introduction of a stream of new and profitable medicines, are likely to rise 10 to 15% this year and do at least as well again in 1991. Profits, moreover, will at least match that pace both this year and next.

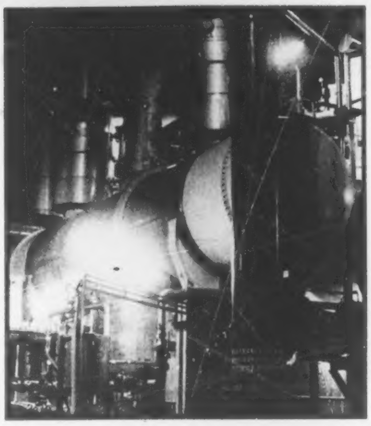
These specialty areas of strength will keep sales of the broad chemicals and allied products industry on the uptick during the year ahead. And though profits for the overall industry can be expected to sag about 5% in 1990, they are likely to recover all that loss in 1991. □

Production of most major chemical products is heading lower

	1988	1989	1990	1991
INORGANIC CHEMICALS				
Thousands of tons unless otherwise indicated				
Ammonia	16,821	16,362	16,450	16,700
Chlorine gas	11,257	11,161	10,800	10,400
Hydrochloric acid	2,640	2,628	2,300	2,150
Nitric acid	7,991	8,349	7,700	7,900
Oxygen, billions of cu ft	452	452	460	450
Phosphoric acid	11,659	11,737	12,100	12,350
Sodium hydroxide	10,527	11,075	11,750	11,350
Sulfuric acid	42,580	43,301	44,300	45,000
ORGANIC CHEMICALS				
Millions of lb unless otherwise indicated				
Acetic acid	3,159	3,537	3,500	3,300
Acetone	2,303	2,497	2,500	2,300
Acrylonitrile	2,609	2,355	2,700	2,500
Benzene,[a] millions of gal	1,608	1,585	1,600	1,400
Butadiene	3,169	3,094	3,000	2,700
Caprolactam	1,261	1,312	1,300	1,250
Cumene	4,455	4,535	4,150	4,000
Cyclohexane	2,297	2,389	2,300	2,100
Ethylene	37,204	34,953	36,000	34,500
Ethylene glycol	5,517	5,499	4,550	4,200
Formaldehyde	6,280	6,374	6,250	5,800
Methanol	8,142	7,139	7,700	7,200
Phenol	3,562	3,892	4,150	3,800
Phthalic anhydride	999	1,102	950	900
Propylene	21,224	20,027	21,500	20,400
Styrene	8,984	8,129	7,900	7,400
***o*-Xylene**	971	842	875	800
***p*-Xylene**	5,601	5,494	5,200	5,000
PLASTICS				
Millions of lb				
Polyethylene, high density	8,400	8,102	8,100	7,800
Polyethylene, low density	10,397	9,695	10,800	10,300
Polypropylene	7,274	7,238	8,000	7,600
Polystyrene	5,187	5,104	5,000	4,600
Polyvinyl chloride	8,350	8,478	8,900	8,500
SYNTHETIC FIBERS				
Millions of lb				
Acrylic and modacrylic	588	543	510	460
Nylon	2,669	2,740	2,700	2,400
Olefin and vinyon	1,588	1,639	1,850	1,800
Polyester	3,681	3,594	3,150	2,900

a Petroleum refiners only. **Sources:** Bureau of the Census, International Trade Commission, Society of the Plastics Industry's Committee on Resin Statistics, Fiber Economics Bureau, C&EN estimates (for 1990 and 1991)

Foreign Trade



Chemical industry awaits trade talk results

Even lackluster export performance seems less important than outcome of GATT negotiations

Earl V. Anderson
C&EN Northeast News Bureau

The chemical industry's foreign trade experts have set aside their statistics, at least for the time being. Those statistics are not all that spectacular this year, in any event. Their eyes, however, have been more focused in recent months first on Geneva and then, more recently, on Brussels.

In Geneva, negotiators at the massive Uruguay round of multilateral trade talks have been working to put the finishing touches on four long and arduous years of negotiations. The talks, the most ambitious ever by the General Agreement on Tariffs & Trade (GATT), encompass foreign trade in agriculture and services, as well as investment rules and, as usual, tariffs and nontariff barriers.

But even after four years, negotiators in the 15 individual committees have been unable to agree on many key issues. So as they packed their bags late last month to leave Geneva, agreement on many important issues seemed out of reach.

The focus switched to Brussels last week, the deadline set for completing the Uruguay round. There, ministerial-level representatives of the nearly 100 countries taking part in the trade talks met to put their stamp of approval on the agreements worked out by exhausted negotiators in Geneva.

At C&EN's press time, there was precious little to stamp. What the trade ministers found in Brussels were committee reports, some with pages blank and others cluttered with "bracketed text"; the brackets indicate wording that had not yet been agreed upon. Only if the trade ministers are able to make some very tough political decisions will the Uruguay round stand a chance of being salvaged.

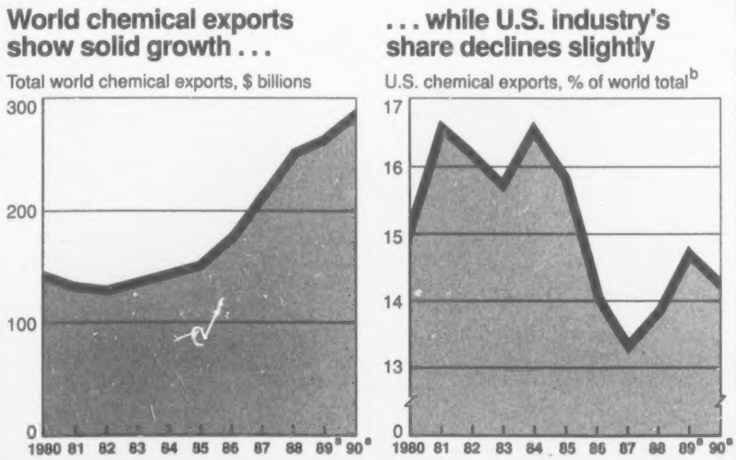
The make-or-break issue in the Uruguay round is agriculture. The farm issue pits the U.S. and the so-called Cairns group of 14 countries that are major agricultural exporters against the European Community.

The U.S. and the Cairns group want deep cuts in domestic farm supports and export subsidies. The EC, where farmers are heavily subsidized and carry a lot of political clout, has offered much less—so much less that the Cairns nations have threatened to walk out of the Uruguay round unless the EC vastly improves its offers.

But agriculture is not the only sensitive—and unresolved—Uruguay round issue. Trade in such services as banking, insurance, and engineering is probably the most complicated. And many concerns regarding protection of intellectual property remain unresolved.

Rules covering foreign investment, one of several matters new to GATT, also still are not completely resolved. Basically, developing nations want foreign investment tied to performance requirements, such as mandatory export volumes and the use of domestic raw materials. Industrialized nations want foreign investment unfettered.

Globally oriented U.S. chemical companies are concerned about



World chemical exports show solid growth . . .

Total world chemical exports, $ billions

. . . while U.S. industry's share declines slightly

U.S. chemical exports, % of world total[b]

a C&EN estimates. b Defined as U.S. chemical exports as percentage of world chemical exports less U.S. chemical imports.
Sources: United Nations, Organization for Economic Cooperation & Development, European Community, Japanese Ministry of International Trade & Industry

Plastics and pharmaceuticals spur growth in U.S. chemical exports

	U.S. chemical exports				U.S. chemical imports			
$ Millions	1990[a]	1989	1988	1987	1990[a]	1989	1988	1987
Organic chemicals	$10,032	$10,609	$ 9,381	$ 7,550	$ 7,298	$ 7,042	$ 6,953	$ 5,408
Plastics and resins	8,740	7,928	7,277	5,492	3,805	3,316	2,433	1,987
Medicinals and pharmaceuticals	4,028	3,660	3,941	3,182	2,403	2,086	1,859	1,456
Inorganic chemicals	2,660	2,986	2,702	2,122	2,158	2,239	2,498	2,030
Fertilizers, manufactured	2,470	2,821	2,498	2,259	935	999	1,021	795
Flavors, perfumes, cosmetics, and toiletries	1,330	1,053	709	579	1,090	968	932	796
Pigments, paints, and varnishes	1,178	772	449	411	579	515	395	427
Radioactive materials	1,102	1,333	868	1,017	979	992	1,098	1,012
Cleaning and polishing materials	608	416	395	357	245	197	260	205
Dyeing, tanning, and coloring materials	418	325	258	217	712	618	610	621
Explosives and pyrotechnics	152	123	91	91	156	131	118	110
Miscellaneous	5,282	4,459	3,731	3,114	1,890	1,649	1,699	1,366
TOTAL	**$38,000**	**$36,485**	**$32,300**	**$26,381**	**$22,250**	**$20,752**	**$19,876**	**$16,213**

a C&EN estimates. **Source:** Bureau of the Census

many of these issues. But by far the most important for them is market access. "Market access" refers to the linkage between negotiations on tariffs and nontariff barriers (or measures, as they now are called). From the outset, chemical industry representatives have been telling U.S. trade officials that they don't want to see the Uruguay round degenerate into a simple tariff-cutting exercise. If tariffs are to be reduced, the U.S. chemical industry also wants negotiators to dismantle many of the nontariff barriers that keep its exports out of foreign markets.

"Market access is nowhere near finished," said Max L. Turnipseed as the trade ministers were preparing to assemble in Brussels. Chemical industry advisers worked feverishly with U.S. officials to prepare a final document on market access before the meeting. But Turnipseed, who is Ethyl Corp.'s manager of international trade, wasn't optimistic.

The EC had made a late offer to eliminate tariffs on some petrochemicals and plastics and to harmonize others at "mid-range" tariff rates. But its offer hinged on other petrochemical-producing countries agreeing to do the same.

The U.S. and the EC were not too far apart, says Turnipseed. But some of the newly industrialized countries, such as Taiwan and South Korea, as well as Mexico and Brazil, would have no part of the deal. "I think it's dead," says Turnipseed.

Several reasonable offers have been made on chemical tariff cuts, with the U.S. offer "more reasonable," in the view of the U.S. industry than the others. But without movement on nontariff barriers, the U.S. chemical industry wants U.S. trade officials to walk away from the table. It would rather see no deal at all than what it considers a bad deal.

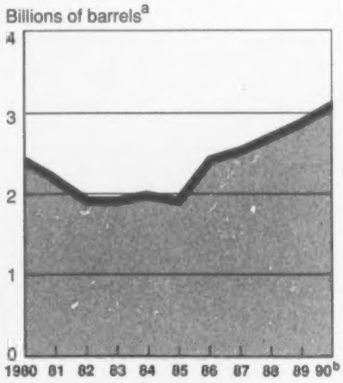
Administration officials claim that they feel the same way. But there's no guarantee that their definition and the industry's definition of good and bad are the same. Even if high-level trade ministers were to agree in principle on a market access package in Brussels, it would take well into January to work out the details. And right now, time is not on the side of the negotiators.

The Uruguay round was scheduled to end three days ago. U.S. trade officials have been reluctant to extend negotiations beyond then, although they may do so if "enough political will" surfaces at Brussels.

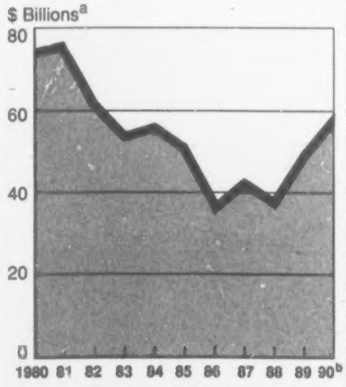
Still, a market access package will have to be completed by mid-January if the Bush Administration is to have enough time to prepare the results for Congress. Legislators must give these results "fast-track" treatment when they get them. This means that they have to vote up or down on the package, without amendments.

But to get this fast-track attention, the Administration must have its Uruguay round agreements on Cap-

U.S. oil imports: higher volume this year . . .



. . . and much higher prices send oil import bill soaring



a All petroleum products. b C&EN estimates.
Source: Bureau of the Census

itol Hill by March 1. It is a deadline they can hardly afford to miss, because already many members of Congress are pushing to do away with the fast-track approach.

By now, the trade ministers who met in Brussels last week may or may not have resolved some of the many contentious issues that plagued the Uruguay round. One thing is certain, however. Whatever decisions come out of the Brussels meetings will have a major impact on chemical trade worldwide.

But Uruguay round or no, chemical trade goes on. Unfortunately for the U.S. chemical industry, it isn't going on so spectacularly this year as it has in recent years.

U.S. chemical exports probably will hit $38 billion this year. That's a lofty figure, but only 4% higher than last year's $36.5 billion. Coupled with a 7% jump in U.S. chemical imports, the small advance in exports keeps the country's surplus in chemical trade at $15.7 billion, just about the same as last year. This relatively low growth in chemical exports is surprising, because the U.S. dollar has been weakening all year. As of late last month, it had lost 15% of its value against the German mark and 11% against the Japanese yen since the end of 1989.

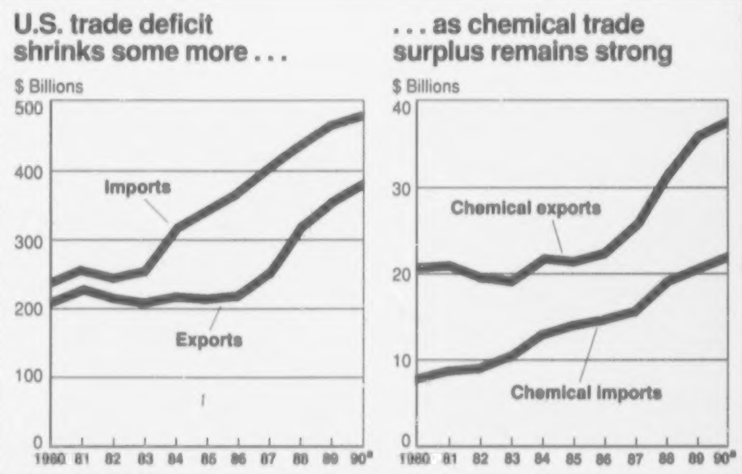
Theoretically, a weak currency helps exports by making them less expensive on world markets than products produced in strong-currency countries. But in practice, exports often defy theory.

One possible explanation is that world prices for crude oil are set in dollars. As a result, countries with strong currencies can buy more dollars and hence get more oil for their money. Many overseas producers of petrochemicals use oil-based naphtha as their feedstock. As a result, they are benefiting from the weak dollar on the raw materials end at the same time that U.S. exporters are benefiting in the marketplace. The net result: something of a standoff.

A more mundane reason for the slow growth in chemical exports is that some overseas markets are starting to satisfy their own demand with local production. Exports of organic chemicals, the largest single category of U.S. chemical exports, is off more than 5% this year from last year. Most of that drop is a result of weaker markets in Asia, where several countries have increased their own petrochemical output.

This year's chemical exports from the U.S may be even worse than they seem. The Census Bureau is revising last year's statistics on exports to Canada. These adjustments may show that last year's chemical export total for the U.S. actually was $38 billion, instead of $36.5 billion. If so, this year's chemical exports will have shown no growth compared with last year. And this year's chemical trade surplus will be $1.5 billion less than last year.

But chemical industry trade experts won't have much time to analyze trade statistics. Not only will they have to contend with the aftermath of the Uruguay round, they also will have to start concentrating on the potential impact on their business of the upcoming free trade talks between the U.S. and Mexico. □


U.S. trade deficit shrinks some more . . .

. . . as chemical trade surplus remains strong

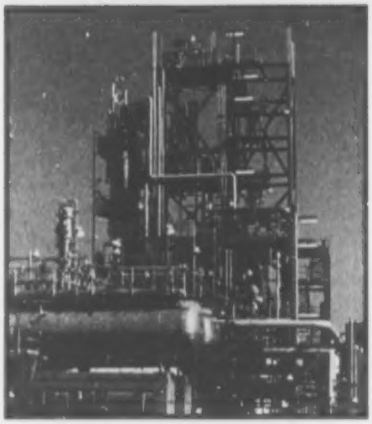
a C&EN estimates. **Source:** Bureau of the Census

Strong manufactured goods exports cut U.S. trade deficit despite higher oil imports

$ Billions	U.S. exports				U.S. imports			
	1990ª	1989	1988	1987	1990ª	1989	1988	1987
Chemicals	$ 38.0	$ 36.5	$ 32.3	$ 26.4	$ 22.3	$ 20.8	$ 19.9	$ 16.2
Machinery and transportation equipment	171.0	148.8	135.1	108.6	204.4	205.6	197.0	177.8
Other manufactured goods	69.9	59.8	47.3	36.5	141.3	138.5	131.9	118.6
Crude materials (inedible) other than fuels	27.0	26.9	25.1	20.4	14.7	15.4	13.4	11.5
Mineral fuels, lubricants, and related materials	10.8	9.9	8.2	7.7	59.9	52.5	41.1	44.2
Food and live animals	29.3	29.7	26.4	19.2	22.2	20.6	20.1	20.5
Beverages and tobacco	6.2	5.5	4.5	3.7	4.4	4.4	4.1	4.1
Animal and vegetable oils and fats	1.1	1.4	1.	1.0	0.8	0.7	0.8	0.6
All other products	14.3	31.2	27.5	20.4	17.0	14.4	12.6	12.4
TOTAL	**$386.0ᵇ**	**$364.3ᵇ**	**$322.4ᵇ**	**$252.9ᵇ**	**$487.0**	**$472.9**	**$440.9**	**$405.9**

a C&EN estimates. b Includes reexported imports (not included in individual product categories). **Source:** Bureau of the Census

Western Europe



Feedstock costs hurt firms' profits

Fallout from Mideast, softening economies overshadow rebuilding in East Europe

Patricia L. Layman
C&EN London

For the chemical industry of Western Europe, this clearly has been the year of Eastern Europe—although developments there were being overshadowed during the second half of the year by the Middle East crisis, which sent costs of oil-based feedstocks soaring and twisted profit margins.

Moreover, these factors—efforts to rebuild the chemical industry in the old East Bloc and the struggle to cope with a volatile and distorted feedstock price base—will continue to dominate the Western European chemical industry in 1991.

December brings down the curtain on an extraordinary year. Business was fair during the first six months, if not exactly earning plaudits. Even so, the unusually high profit margins companies had enjoyed during the two previous years, which were due in part to high demand that had overstretched capacity, were settling down to more sustainable levels. Although raw material costs were rising slowly, companies were finding some difficulty in passing along higher prices, as customers awaited increases in product availability as new capacity came on stream. But the balance was one the chemical industry could live with, albeit with grumbles.

Iraq's Aug. 2 invasion of Kuwait, however, sent feedstock costs soaring. Naphtha, the major feedstock for Western European ethylene crackers, zoomed from $157 per metric ton average in July to $300 per metric ton by late August; since then, it has continued to increase, at one point topping $400 per metric ton.

According to Bryan Sanderson, chief executive officer of BP Chemicals in London, Western European chemical producers use about 60 million metric tons of naphtha equivalent a year, 80% of which goes into ethylene production. An increase in price of $100 per metric ton thus represents a cost increase to the industry of about $500 million per month.

The results were inevitable for petrochemical producers. As Jürgen Strube, chairman of Germany's BASF, put it late last month, "After crude oil and naphtha prices had doubled, we succeeded rather rapidly in putting in price increases for basic petrochemical derivatives, particularly polyolefins—but they did not suffice to offset the rise in raw material costs. August and September earnings," he added with understatement, "were very unsatisfactory."

The decline in BASF's profits, compared with like periods of 1989, is mirrored by those of other major European chemical producers, such as fellow German giants Hoechst and Bayer; Britain's ICI, BP Chemicals, and Shell; the Netherlands' Akzo and DSM; and France's Rhône-Poulenc. Because earnings were at record levels in 1988 and 1989, it is no surprise for there to be a drop in profit levels this year—although it probably would not have been as steep or dramatic were it not for the Middle East crisis.

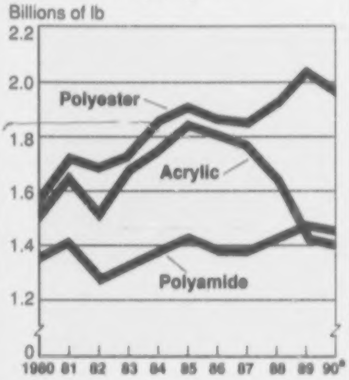
The only companies that have been reporting earnings increases for the year are those whose operations are far enough downstream from basic chemicals—for example, in consumer product areas such as pharmaceuticals or in specialty chemical markets—to escape the direct brunt of petrochemical price effects.

On the other hand, even these Western European companies have all been hit by adverse currency exchange rates, particularly that of the U.S. dollar, which weakened significantly after the invasion of Kuwait. Profits transferred by such companies from the U.S., for example, or from such other dollar-important areas as Japan and elsewhere in the Far East, can trim sizable amounts from a company's net income. The other side of the coin, of course, is that when the European subsidiaries of U.S. chemical firms transfer their profits from strong European currencies into weaker dollars, reported earnings improve significantly.

Chemical companies are beginning to have some success in passing rising feedstock costs along to their customers. It seems clear, nonetheless, that 1990 will be at best no more than a fair-to-middling year for chemical company earnings.

Coupled with a decline in profits, production for the West European industry as a whole has also dropped off compared with 1989. Late last year, chemical industry executives were optimistically forecasting that production in 1989 would be up 3.5 to 4% over 1988, and that 1990 would continue that growth pattern very closely. There was little likelihood, executives believed then, of a decrease in production, let alone a recession.

Fiber output little changed in past couple years



a Estimates. **Source:** CIRFS (International Rayon & Synthetic Fibers Committee)

By the middle of 1990, however, signs of slowdown were becoming clear. CEFIC, the European Chemical Industry Federation, predicted in its annual report issued in June that chemical output growth would slow to about 2.5% in 1990, a growth rate that would be lower than that for all manufacturing. The final figure for full-year 1990 undoubtedly will be significantly lower still.

For 1991, the catchwords seem to be "caution" and "uncertainty." Executives at Shell International Chemical in London note that although some degree of market stability is now emerging, the underlying trend remains uncertain and very sensitive to potential Middle East developments. Optimism for 1991 is overshadowed by a wait-and-see attitude. And Akzo officials predict that "a turnaround will probably not take place in the short term."

That assessment is echoed by Sir Denys H. Henderson, chairman of ICI. Speaking late last month before the Society of Business Economists, he said that there is "no doubt" that the U.K., as well as the U.S., Australia, and Canada, have been in recession for some time, and that there still is little evidence of any soft landing, fall in interest rates, or business recovery. His own prediction is that the current downturn will last for 12 to 18 months, with "little likelihood of a pickup until the second half of 1991 at the earliest." For a really solid economic recovery to proceed, he added, the Kuwait crisis must be resolved, oil prices must fall back to what he sees as a "real" level of $20 a barrel, and interest rates must fall worldwide.

One of the few "certainties" that remain for West Europe's chemical industry is the appeal of Eastern Europe.

Compared with such Western European industries as banking and telecommunications, which rushed into Eastern Europe—particularly into the former East Germany—to carve out business, the chemical industry has been taking its time in moving eastward. But its pace of activity also has begun picking up.

Chemical companies have been sending delegates to the plethora of conferences that are being held now on business opportunities and on the "hows-and-whys" of doing business in the East. They have been sending representatives to the Eastern countries to reconnoiter, meet people, and become acquainted with possible venture partners or acquisitions. And they have begun setting up sales offices there to begin to learn about customers, markets, and selling methods. And this groundwork is beginning to pay off: West European chemical firms are beginning to make strategic deals—joint ventures and partial acquisitions—in selected, specific areas of Eastern Europe.

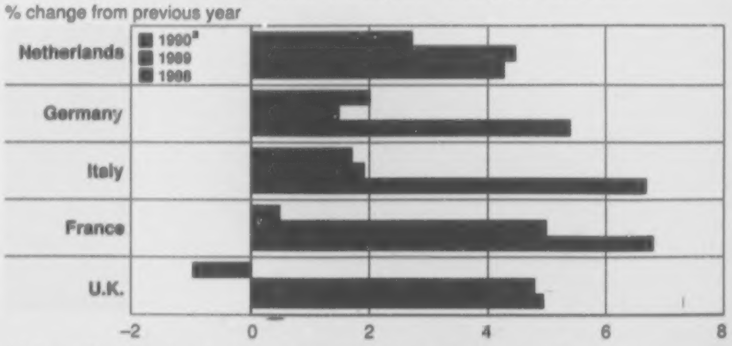
As part of their preliminary work, companies are trying to pin down a variety of factors, including enabling legislation in the different countries, environmental conditions, and the condition of plants and equipment. There actually may be some pleasant surprises in Eastern Europe, says Alan Plaistowe, president of consultants Chem Systems International of London. "We are coming to the conclusion that the capital stock of the industry may not be as bad as everyone seems to think. Some of the more modern, larger plants and refineries have some chance of survival with selective modernization."

Chemical companies within western Germany are leading the way into the east, although firms elsewhere are getting the itch as well. A case in point is BASF, which recently acquired Synthesewerk Schwarzheide, which had been the only urethane maker in East Germany and was one of only a few urethane suppliers to the rest of the East bloc.

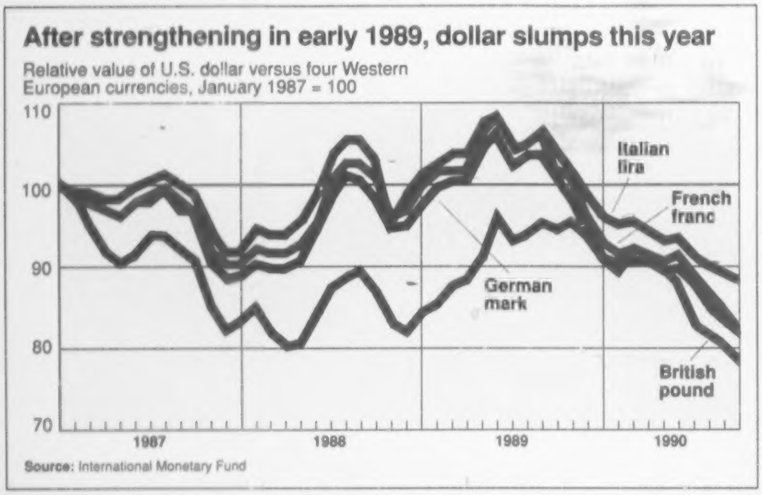
BASF took over Schwarzheide at the beginning of November, so its sales are not yet being consolidated with the Ludwigshafen parent. But according to one report, Schwarzheide is ultimately expected to contribute up to a quarter of BASF's sales of urethanes. BASF will not be held liable for Schwarzheide's previous chemical pollution. However, the company has already said it will put roughly $340 million into the former East German plant, much of it for environmental cleanup of plant and infrastructure, according to Strube.

Additionally, BASF has a cooperation agreement with animal feedpremix maker Dr. Ponsold GmbH of Saxony-Anhalt. BASF will give tech-

Pace slackens for chemical output of top producers



a Estimates. **Sources:** National chemical federations, CEFIC (European Chemical Industry Federation)



After strengthening in early 1989, dollar slumps this year

Relative value of U.S. dollar versus four Western European currencies, January 1987 = 100

Source: International Monetary Fund

nical and commercial help in meeting the West German laws and regulations on feed that now apply throughout Germany. Dr. Ponsold is the leading manufacturer of premixes in the five Eastern European states.

BASF's Wintershall energy subsidiary also has worked out an agreement with Gazprom, of the Soviet Union, for joint projects to produce, clean, and subsequently process natural gas for industry and homes. Gazprom probably is the world's largest producer, transporter, and exporter of natural gas, and this deal marks the first private direct equity participation by a Soviet enterprise in the West, according to BASF.

Hoechst is holding talks with Lacke und Farben of Berlin regarding cooperation in the areas of paints, lacquers, and resins for industrial applications. Hoechst is also negotiating to acquire some of the operations of Technische Gase Leipzig (TEGA Leipzig). To augment this, Hoechst plans to build a major air separation plant in eastern Germany.

Meanwhile, Air Liquide has already purchased a distribution network for cylindered industrial gases in eastern Germany and the industrial gas production and distribution sites of TEGA Berlin, as well as some operations of TEGA Leipzig. Air Liquide also plans to build a plant in the Leipzig area for producing oxygen, nitrogen, and argon.

Glaverbel, a Belgian flat-glass maker controlled by Japanese producer Asahi Glass, has made a major investment in SkloFlat, the state-owned Czech glass company. Glaverbel acquired 40% of SkloFlat for about $48 million. After three years, Glaverbel can increase its share to 65%.

French oil firm Elf Aquitaine, too, is holding discussions with Czech officials dealing with energy and chemicals. And Finnish producer Neste Chemicals has appointed representatives in Warsaw and Prague to market its products and sound out business opportunities, a job previously handled by Neste Chemicals' offices in Vienna.

Neste is already well along in talks with Czechoslovakia's CHZ Litvinov to market polyethylene plastics and carry out polyethylene product development. According to Jukka Viinanen, executive vice president at Neste Chemicals, "The discussions are going very well; it is obvious we will reach an agreement on polyethylene."

In a move to beef up its presence in Eastern Europe, the U.K.'s ICI is shaping its representative liaison offices in each East bloc country to become wholly owned subsidiaries, with the freedom to conduct their own business affairs.

And Akzo has already set up a coatings joint venture with TVK in Hungary, as well as formalized a cooperative agreement with Finowtal, a producer of carboxymethyl cellulose, in eastern Germany.

In part, just being there is one of the most significant commitments a western company can make, suggests Basil Vassiliou, who heads Rohm & Haas' European operations. For example, Rohm & Haas has had a joint venture in Yugoslavia since the early 1970s that it counts as a success in building sales—some 5% of the company's total sales are in Eastern Europe—and in getting to know the territory.

Akzo's East European experts note that the markets there offer a number of opportunities. One of the most important is that by restructuring the industries in the East bloc western companies can now approach customers there more directly and with more technical support. "This implies that customers can be treated in the way we do it in western markets as well," says one Akzo executive.

There is also opportunity, add officials at DSM, in providing western technology and managerial skills in exchange for products or for ownership of a project.

Rohm & Haas' Vassiliou agrees, but notes that caution is still needed: "How much money do you want to invest in this part of the world? You don't know the countries, so can you really take advantage of them? Can the people there solve their environmental problems? Can you get quality that will be acceptable? And how reliable is supply?"

Uncertainties in Eastern Europe, however, can be lived with more easily than those affecting general economic conditions in Europe during the coming year.

Third-quarter earnings of Western European chemical firms were poor primarily because of losses stemming from foreign currency translation and the large rise in raw material prices. In fact, unfavorable currency exchange rates more than offset any benefits resulting from

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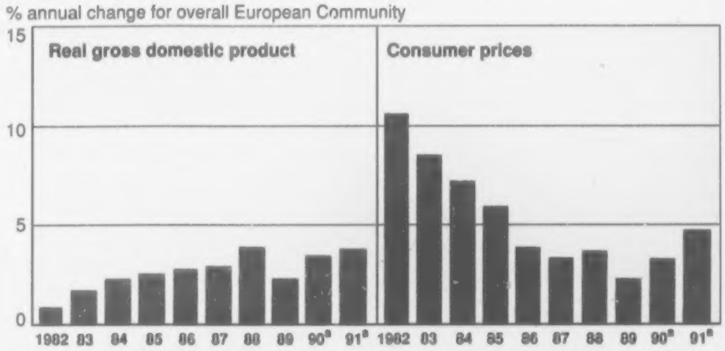
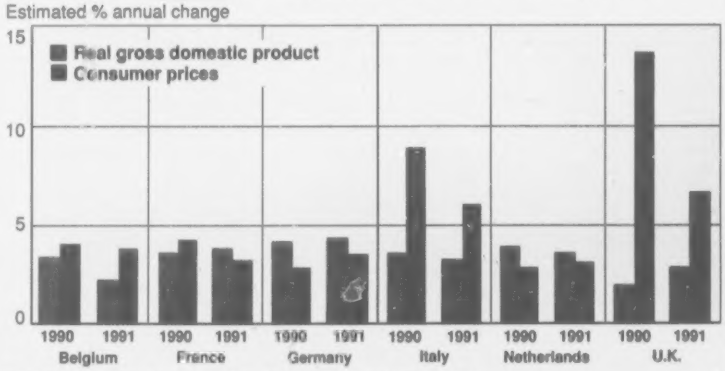
Inflation quickens as expansion in Europe continues . . .



. . . with growth generally expected to be steady in '91



a Estimated. **Sources:** Commission of the European Community, Barclays Bank

hydrocarbon feedstocks being priced in weak U.S. dollars. Athough the cost of a barrel of crude oil was rising, the rise was denominated in weak dollars, so the net rise in costs to European petrochemical companies was not so steep as face value might indicate.

However, according to Alastair Kilgour, a chemicals analyst at BNP Securities in London, currency fluctuations and increases in raw material prices will have much less effect on chemical firms' earnings in 1991. Product prices also are rising, and both demand and capacity utilization have continued to be generally high.

Nonetheless, he adds, "We are cautious. The real key to profitability is capacity utilization. As this falls, the current pricing discipline in the market will come under increased pressure. We perceive the crunch coming in the first quarter 1991, when volumes could slow significantly."

Growth in demand will slow, adds Tony Church, an analyst with Wertheim Schroder, an investment securities firm in London, for one thing, because of the reaction of individual governments to rising inflation. "We believe that government action to control inflation in continental Europe will be harsh, leading to a more significant fall in the rate of economic activity than currently anticipated, thereby weakening demand," he says.

Given the slowing growth in demand, no apparent shortage of material, and the lack of a clear consensus on how producers are approaching price rises, Church believes that pressures on profit-margins of commodity chemical companies will increase sharply. Higher costs will be passed through to customers only with difficulty during the next three or four months, so that ultimately selling prices will fall short of full cost coverage.

He does point out one positive development, however. The potential slowdown in demand is causing a cutback in plans for new chemical plant construction around the world. Perhaps the primary example of this is Exxon Chemical's delay, by about two years, of a major expansion of its Fife ethylene plant at Mossmoran, Scotland, which it operates as a joint venture with Shell Chemical.

This year will also see global trading patterns begin to change, a number of companies indicate. The major reason is that capacity continues to build up in the Far East, although there is doubt about the economic viability of some of the large projects there.

Corporate executives throughout Europe are watching for signs of downturn. For example, Hermann J. Strenger, chairman of Bayer, concludes that an economic slowdown already is under way in the U.K. and the U.S., with signs of one also appearing in Spain, Italy, France, and Scandinavia. Demand thus far remains buoyant, he says. But he sees excess capacity in some areas, coupled with upward pressure on selling prices from the soaring prices of crude oil and petrochemical feedstocks, as negative factors that companies must cope with.

Bayer, he says, will do everything it can to raise selling prices so as to pass along its higher costs to the market. At the same time, it is implementing cost-cutting measures to check rising costs in all areas, from maintenance to marketing and administration.

One of the problems faced by petrochemical companies, in particular, according to James Gordon, chemicals coordinator for Shell International Chemical, is that "prices for some if not most chemical products are still not at the same level, in real terms, that they were in 1988 despite a doubling of feedstock prices. That is causing a severe effect on margins." It's not such a bad situation for customers, he adds—"they are not in nearly as bad a squeeze." Companies like Shell, however, are "caught in the middle." ◻

Japan

Chemical boom may now be faltering

An end to Japan's 48 months of economic growth would mean problems for Japanese chemical companies

Earl V. Anderson
C&EN Northeast News Bureau

The heady price of membership in Japanese golf clubs is coming down—far and fast. Could this be a harbinger of economic trends for the nation's chemical industry, where golf club membership is considered a gold-plated investment as well as an expensive route to recreation?

It could be. The Japanese have just completed their 48th consecutive month of economic expansion, the longest period of growth for the country since a 57-month streak in the late 1960s. Now, however, the high oil prices triggered by Iraq's invasion of Kuwait threaten to halt Japan's current expansion binge.

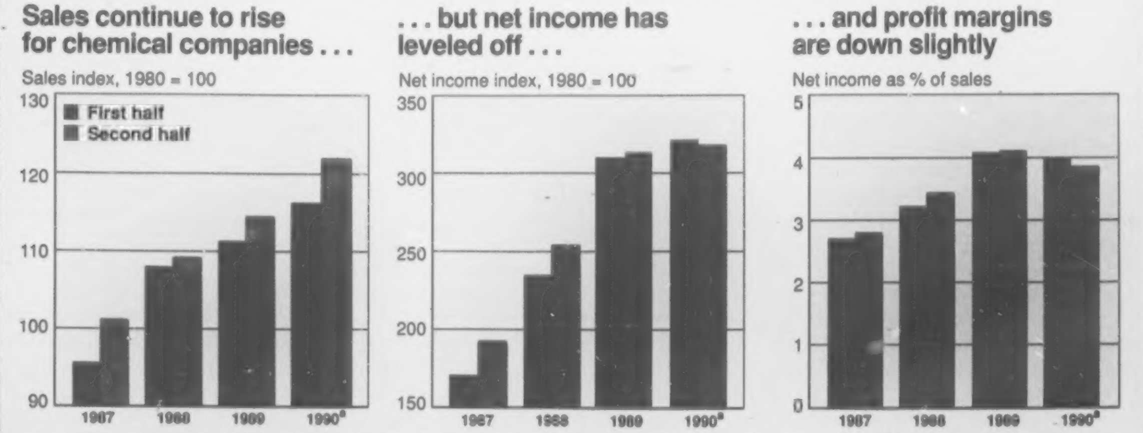
Oil prices are not the only problem facing Japan's economy. In fact, an exceptionally strong yen has offset much of the impact of high world oil prices, which are set in dollars. Inflationary pressures, high interest rates, and an expected drop in capital spending are other culprits.

Inflation could dampen personal consumption, one of the engines that have kept Japan's economy growing at an estimated 4 to 6% this year. Rising interest rates, in addition, will mean higher payments for heavily leveraged Japanese companies. Business capital spending contributes about 20% to Japan's gross national product.

Government officials estimate that the economy will grow about 3% in fiscal 1991, which starts next April. But many Japanese business executives are skeptical. They suspect that economic growth may be halted altogether, or even reversed in coming months.

Japanese manufacturing companies must cope with these gathering storm clouds, and chemical companies are no exception. However, for the chemical industry, there is the added burden of high naphtha prices, the result of continuing tensions in the Middle East. Japan's petrochemical industry depends heavily on naphtha—particularly imported naphtha—for its feedstock.

As a result, many executives in Japanese chemical companies believe that the industry is sailing into much rougher economic seas. A recent survey conducted by the Japan Chemical Industry Association (JCIA) bears this out.



Note: Based on the results of 12 leading Japanese chemical companies: Asahi Chemical Industry, Dainippon Ink & Chemicals, Hitachi Chemical, Mitsubishi Kasai, Mitsubishi Petrochemicals, Mitsui Toatsu Chemicals, Sekisui Chemical, Showa Denko, Sumitomo Chemical, Takeda Chemical Industries, Teijin, and Toray Industries. The fiscal year for most, but not all, of these Japanese companies ends March 31 of the following year. a Estimated for second half. **Source:** Toto Kwizai, Shinposha

The survey found that chemical production, sales, and profits have remained strong through the first three quarters of the year (or through the first half of Japan's fiscal 1990, which ends next March 31). Now, says JCIA, indexes for the chemical industry, particularly in the petrochemical and organic chemicals sectors, are declining.

The situation in the Middle East colors much of the JCIA survey. Most respondents believe that raw material costs will continue to escalate, which is bad for their businesses. The survey shows clearly that Japan's chemical industry has been faring very well. This is especially true of inorganic chemicals, and to a lesser extent for petrochemicals and organics.

Chemical industry leaders aren't that optimistic about the future, however. According to JCIA, although most of them think that business conditions will remain unchanged throughout the quarter ending this month, the number thinking that way is far less than in the previous survey about three months ago. And those who think that the situation will take a turn for the worse far exceed those who think that it will improve.

What's more, the situation looks even worse to these Japanese chemical executives as they peer further out. More than half expect business conditions to get worse in the first quarter of 1991 (the last quarter of Japan's fiscal 1990). And although they concede that next year's second quarter is unpredictable, most think the situation then will be worse.

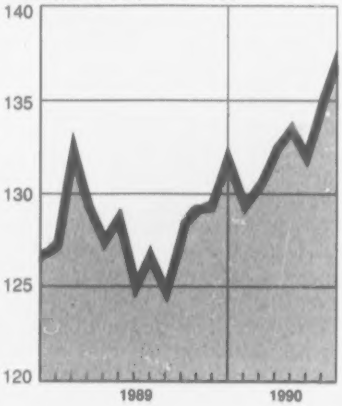
That's not an encouraging scenario, but chemical executives are not alone in their pessimism. According to another survey, the consensus of 267 Japanese manufacturing companies is that pretax profits in fiscal 1990 will decline 1%—this despite broadly higher profits in the first half, ending in September.

The survey conducted by Nihon Keizai Shimbun, a business newspaper publisher, reflects the general belief that growth in the economy will slow in 1991, after four years of expansion. It also indicates that even in the last three months of 1990, many companies have felt the impact of higher interest rates, a very

Chemical production continues to grow in most areas

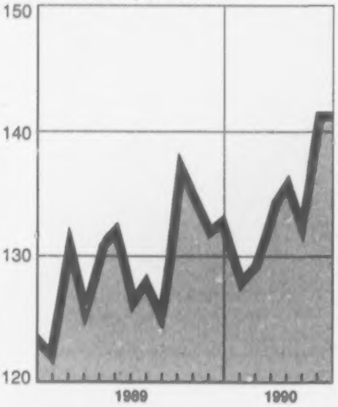
All chemicals

Production index, 1985 = 100[a]



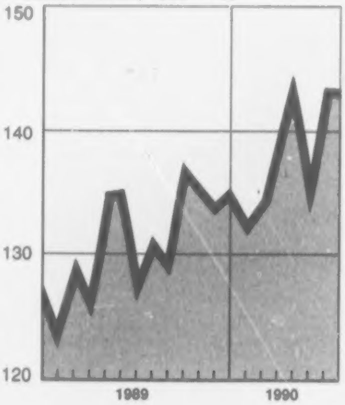
Petrochemicals

Production index, 1985 = 100[a]



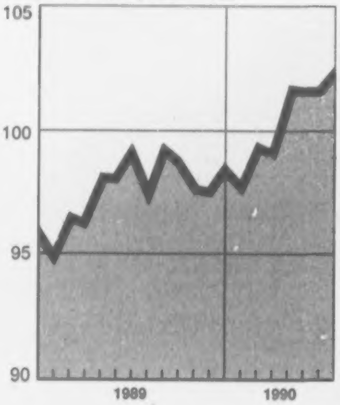
Plastics

Production index, 1985 = 100[a]



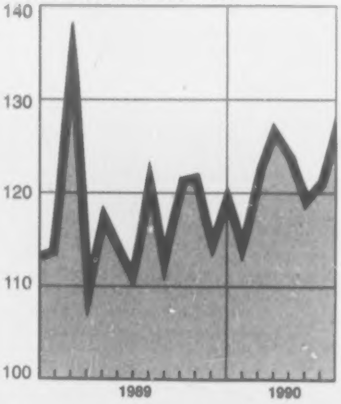
Synthetic fibers

Production index, 1985 = 100[a]



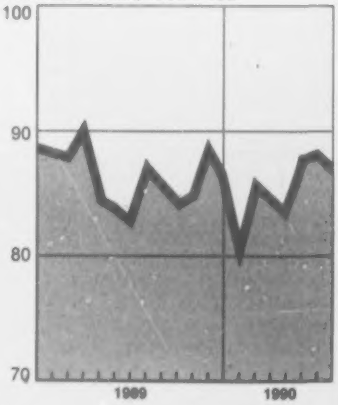
Synthetic rubber

Production index, 1985 = 100[a]



Fertilizers

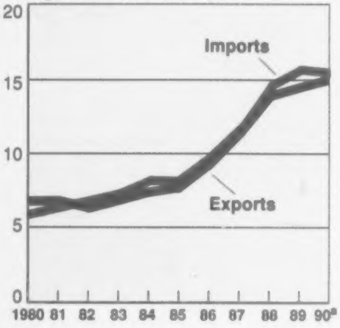
Production index, 1985 = 100[a]



[a] Seasonally adjusted. **Source:** Ministry of International Trade & Industry

Deficit in Japan's chemical trade narrows

Foreign trade in chemicals, $ billions



a C&EN estimates.
Source: Ministry of International Trade & Industry

strong yen, higher crude oil prices, and the plunge in the Japanese stock market.

A C&EN index of the net income of 12 leading Japanese chemical companies confirms this trend, as far as the chemical industry is concerned. Their profits rose 3% in the first half of fiscal 1990 but will decline about 1% in the second half. That's certainly not a wipeout. But it isn't a welcome prospect, either, to a chemical industry whose profits have jumped 112% since the second half of fiscal 1986, while sales increased only 28%.

Until very recently, the Japanese chemical industry had been on a roll. In some cases, it was cranking out record volumes of material and still couldn't meet demand.

Last year, for instance, it produced a record 5.6 million metric tons of ethylene. Through August 1990, output was 4% ahead of last year's pace. If that rate of growth is maintained, ethylene production could hit 5.8 million metric tons in 1990. But domestic demand is estimated to be 5.7 million metric tons this year, and that doesn't include exports.

Styrene is another of several petrochemicals that are in tight supply in Japan, even though they are heading for record production levels. For styrene, in fact, the shortage is acute. As of a month ago, stocks were less than two months' supply.

Because of this market tightness, Japanese chemical companies are building or planning major expansions in ethylene and many other major petrochemicals. Now many are wondering if they may have to relearn the lesson of bringing on large chunks of new capacity just when the market is topping out.

Meanwhile, petrochemical producers have been able to raise prices on many products to compensate for higher naphtha costs. But if demand starts dropping, price increases could be hard to come by. And price increases are something the Japanese chemical industry can ill-afford to lose. In October, naphtha costs in Japan rose above $400 per metric ton, $100 higher than a month earlier.

Some ethylene producers are switching from imported to domestic naphtha. But that ploy can do only so much good. First, domestic naphtha still must be produced from expensive imported crude oil. And although the chemical industry has already doubled its reliance on domestic naphtha from 5% to 10%, it still means that 90% of its requirements must be met by imports. ◻

Production of plastics continues to show strong growth

Thousands of metric tons unless otherwise indicated	1989	Eight months 1990	Eight months 1989	% change
INORGANIC CHEMICALS				
Ammonia	1831	1213	1225	−1%
Ammonium chloride	274	169	195	−13
Ammonium sulfate	1717	1212	1147	6
Calcium carbide	344	201	240	−16
Calcium superphosphate	454	321	303	6
Carbon black	779	516	513	1
Chlorine, liquid	1009	686	679	1
Hydrochloric acid	571	395	368	7
Nitrogen[a]	7876	5436	5134	6
Oxygen[a]	8384	5733	5462	5
Sodium carbonate	1105	758	748	1
Sodium hydroxide	3674	2568	2417	6
Sodium silicate	756	508	479	6
Sulfuric acid	6885	4546	4549	0
Titanium dioxide	275	185	181	2
ORGANIC CHEMICALS				
Acetaldehyde	356	245	237	3
Acetic acid	432	292	274	7
Acetone	337	230	219	5
Acrylonitrile	611	385	398	−3
Benzene[b]	2672	1948	1791	9
Butadiene	827	543	541	0
Butanol	291	190	186	2
Caprolactam	469	345	315	10
Cyclohexane	656	437	438	0
Dioctyl phthalate	293	190	192	−1
Ethylene	5602	3797	3648	4
Ethylene dichloride	2464	1759	1613	9
Ethylene glycol	548	342	325	5
Ethylene oxide	681	451	421	7
Methanol	82	62	64	−3
Octanol	285	174	191	−9
Phenol	423	282	275	3
Phthalic anhydride[b]	160	199	105	90
Propylene	4012	2757	2624	5
Propylene glycol	285	193	182	6
Styrene	1990	1372	1314	4
Terephthalic acid	1200	866	810	7
Toluene	1075	726	693	5
Toluene diisocyanate	104	70	66	6
Urea	810	507	537	6
Xylene	2488	1749	1626	8
PLASTICS				
Phenolic resins	375	250	248	1
Polyethylene	2712	1909	1739	10
Polypropylene	1719	1260	1101	14
Polystyrene	1997	1356	1305	4
Polyvinyl chloride	1972	1332	1289	3
SYNTHETIC RUBBER	1352	949	906	5

a Millions of cubic meters. b Petroleum-based product only. **Source:** Ministry of International Trade & Industry

Canada

Chemical companies slide into recession

Sales and earnings are hurt by sagging domestic economy and strong Canadian dollar

Earl V. Anderson
C&EN Northeast News Bureau

Canadian chemical companies are ending up 1990 with a lot on their minds. There is the new Canadian goods and services tax (GST). Then there's the question of Quebec's future relationship with the rest of Canada.

And, of course, there's the current recession.

Barring political complications, the highly controversial GST will go into effect Jan. 1. If it does, prices will change for a wide range of products and services.

GST, a multistage, value-added tax similar to that used in many European countries, will replace the current manufacturers' sales tax. Unlike many consumers in Canada, the export-oriented Canadian chemical industry generally supports GST because it expects the tax to benefit exporters. However, there are a lot of unknowns involved in changing any tax system, especially a change as dramatic as this one.

Also unknown is the future of Quebec. Since the collapse of the Meech Lake package of constitutional reforms in June, Quebec has been debating whether to remain a part of Canada, seek independence, or find some ground in between. The outcome must at least await the results of a Quebec national assembly committee study on the province's constitutional future, due late next March.

What is known, however, is the impact of the recession in Canada on the fortunes of Canadian chemical companies. It isn't good.

Canadian business executives have believed for some time that they were plowing through a recession. Now, it's official. No less a government official than finance minister Michael Wilson acknowledged in October that Canada is, indeed, in a recession.

Wilson does not expect the recession to be severe. Others aren't that sanguine. A *Financial Post* survey of Canadian economists showed that they think the present downturn will be "fairly long and deep," lasting more than one year. It's a far more pessimistic view than they expressed only four months ago.

The downturn in the Canadian economy started in the second quarter. Economists can't agree when it will end. Some look for the economy to bottom out in the second or third quarter of 1991. Others bet on the end of 1991. Still others believe that the slump will continue on into 1992. At least part of this pessimism is based on the belief that the Bank of Canada will keep its interest rates high to combat inflation.

Numbered among the pessimists are several Canadian chemical company executives. J. Edward Newall, chairman and chief executive officer of Du Pont Canada, says, "We expect that the recession in the North American manufacturing sector will continue well into 1991. The overvalued Canadian dollar [which hampers exports], high interest rates, and rising energy and raw material prices are making business difficult for us and our customers."

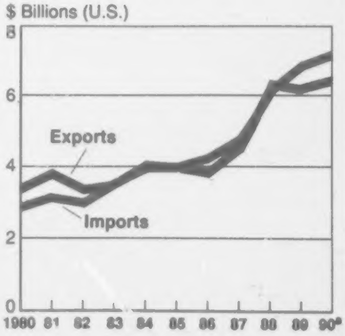
W. Norman Kissick, chairman of Union Carbide Canada, agrees. He says that, with the Middle East situation significantly increasing petrochemical raw material costs and with the Canadian economy deteriorating, "the outlook remains difficult."

They have reason to be less than confident about the immediate future. Du Pont Canada's sales for the first nine months were up only 1% from the year-earlier period, while net income was down a hefty 33%.

Carbide Canada saw its sales drop 3.5% during this year's first nine months and its net income plummet 68%. Many other Canadian chemical companies are in the same boat. At Celanese Canada, for instance, both sales and profits were down 8%. Gerald Elden, president of Celanese Canada, adds: "Margins are suffering and cost increases may not be recoverable in the short term."

Du Pont Canada's Newall notes that, although domestic demand continues to weaken and domestic

Deficit persists for Canada's chemical trade balance



a C&EN estimates. **Source:** Statistics Canada

More gains than losses in chemical output this year

Thousands of metric tons	Production 1990[a]	1989	1988	1987	1986	% change 1989-90
Ammonia	3520	4054	4010	3512	3540	-13%
Ammonium nitrate	1030	1056	981	844	948	-2
Ammonium phosphate	na	952	986	941	1149	na
Benzene	760	670	695	720	635	13
Chlorine	1550	1592	1664	1635	1536	-3
Ethylene	2350	2317	2346	2140	1909	1
Hydrochloric acid, 100%	185	180	180	164	153	3
Phosphoric acid, 100%	400	470	475	464	547	-15
Polyethylene, high density	325	293	311	269	242	11
Polyethylene, low density	1160	1008	1105	1021	887	15
Propylene	755	719	669	628	628	5
Sodium chlorate	650	593	503	432	373	10
Sodium hydroxide	1550	1542	1720	1770	1696	1
Sulfuric acid	3260	3560	3805	3437	3536	-8
Toluene	420	397	417	396	393	6
Urea	2445	2402	2372	2142	2330	2

a C&EN estimates. na = not applicable. **Source:** Statistics Canada

revenues were down 14% in the third quarter, the company's exports were up 35%.

In fact, Canadian exports of chemicals will increase this year, although not so much as Du Pont Canada's did. They are likely to rise 5% (based on Canadian dollars) to the equivalent of $6.5 billion in U.S. currency. Imports, meanwhile, will advance only 3% to $7.2 billion. This will shave $30 million off the chemical trade deficit, which was $815 million (U.S. dollars) last year.

Higher export volumes, despite the strong Canadian dollar, have helped to offset weak domestic markets, making it possible for Canadian companies to increase production of some chemicals this year. This is particularly true of the major synthetic resins. Such increases would not be possible by supplying the Canadian domestic market alone. Nevertheless, output of ethylene derivatives is expected to nudge ethylene production up only about 1% this year to 2.35 million metric tons.

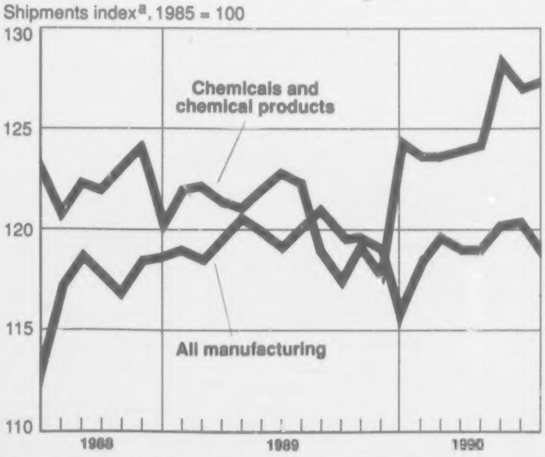
Aromatics are faring much better. Benzene and xylene production are up strongly in Canada this year. Toluene output is advancing more modestly, however. The reason for the strong showing in aromatics: growing demand for octane enhancers that help refiners comply with the phase-out of the use of lead in Canadian gasoline.

Not so fortunate are Canadian fertilizer producers. Ammonia production, for instance, will drop about 13% this year and ammonium nitrate output will decline 2 to 3%, while urea production will inch upward only 2%.

Weak pulp and paper markets, meanwhile, plus a change in that industry's technology, are hurting several inorganic chemicals. For instance, chlorine consumption—and output—is down because pulp mills are trying to eliminate emissions of chlorinated organic compounds.

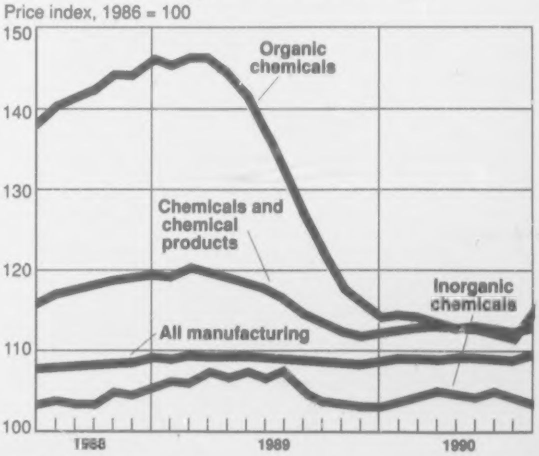
In addition to riding out the recession, Canadian chemical firms will have to focus on three important trade issues next year. One is the Uruguay round of trade negotiations sponsored by the General Agreement on Tariffs & Trade. Another is the list of chemicals it may recommend for a new round of accelerated tariff cuts under the Canada-U.S. free trade agreement. And third is the upcoming free trade talks between the U.S. and Mexico. □

Chemical shipments move higher . . .



a Seasonally adjusted. **Source:** Index based on Statistics Canada shipments data

. . . as chemical prices remain weak

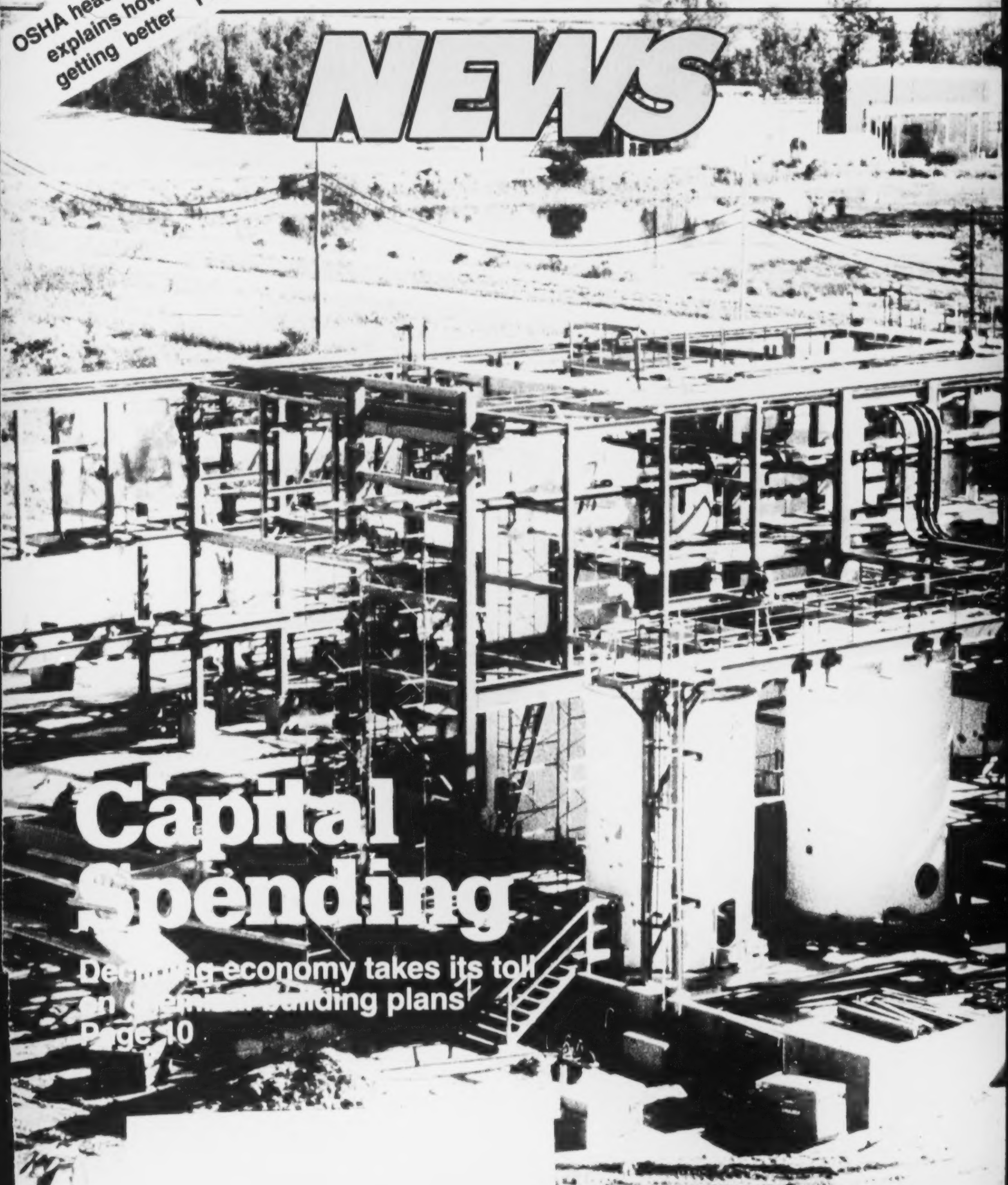


Source: Statistics Canada

DECEMBER 24, 1990

CHEMICAL & ENGINEERING NEWS

OSHA head Gerard Scannell explains how agency is getting better Page 14



Capital Spending

Declining economy takes its toll on chemical building plans
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CENEAR 68 (52) 1–40
ISSN 0009-2347

CHEMICAL & ENGINEERING NEWS

DECEMBER 24, 1990

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- **Scientists express unease at long-term effects of NIH's new, Congressionally mandated plan to contain biomedical research costs.** Page 4
- **Committee reports cold fusion research at Utah institute carried out in sound manner, but future funding is still in question.** Page 5
- **Massachusetts researchers develop series of amino acid fluorides that may prove useful in peptide synthesis.** Page 6
- **Advisory panel recommends FDA allow first-time marketing of bioengineered immunoprotective proteins.** Page 6

Government

OSHA head Gerard Scannell expresses optimism as he discusses his efforts to rebuild confidence in the agency's advocacy for worker safety and improvements in how the agency operates. **Page 14**

Science/Technology

Akron, Ohio, area being revitalized as polymer science and engineering center following its demise as the tire manufacturing capital of the world. **Page 20**

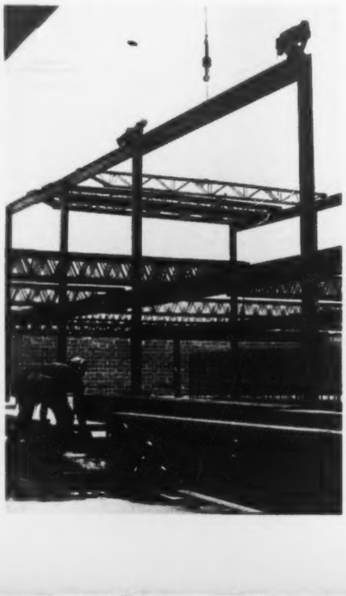
MIT scientists discover decairon molecule, whose coplanar iron atoms are linked via methoxide and carboxylate bridges, and dub it a molecular "ferric wheel." **Page 22**

IUPAC issues new "Red Book" that updates guidelines for naming inorganic compounds and includes new chapters on nomenclature principles and the "grammar" of naming compounds. **Page 22**

ACS News

Nearly a third of ACS's local sections held chemistry week events this year, in spite of no coordinating by national office. **Page 27**

Cover: Mobay's organic pigments plant under construction at Bushy Park, S.C.



Cover Story

Worldwide capital spending by major U.S. chemical companies will slip slightly in 1991, as the weakening domestic economy begins to take its toll. Page 10

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Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036
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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director
Robert H. Marks, Director, Publications Division

PUBLISHING BOARD: Jean'ne M. Shreeve *(Chairman); Board of Directors Chairman:* Joseph A. Dixon; *President:* Paul G. Gassman; Richard L. Deming; William P. Jencks; Gary J. Long; and Louis D. Quin

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Subscription Rates 1990. Printed editions: nonmembers U.S. 1 yr. $60, 2 yr. $108, outside U.S. 1 yr. $93, 2 yr. $174. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $9.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

A terrible addiction

This is a true story. In the late 18th century was born a new country, one destined for greatness. As the years passed, it blossomed into the most powerful country in the world economically, politically, and militarily. There were many reasons it was able to grow to such strength. For one thing, it was blessed with an abundance of natural resources and raw materials to feed its burgeoning industries. For another, the constitution—and the government sworn to uphold it—promised long-term political stability. But most important was the character of its people. They were strong both morally and physically. They were resourceful, independent, freedom-loving people who believed and demonstrated that the only way to make dreams come true was through dedication, hard work, and a good education.

Then, about 100 years ago, something subtle began happening, something that would eventually threaten the very existence of this great and wonderful country. A chemical substance slowly found its way into widespread use by the people in the country. The suppliers of this "wonder" substance promised it would ease the pain and suffering of all mankind. It would deliver the people from their daily drudgery, and make life easy and pleasurable. The people of the country were seduced into believing them.

New industries developed to import increasing quantities of this substance, and to distribute it far and wide. People's thirst for the new substance grew at an alarming rate. Prices escalated and profits soared to the point that billions of dollars eventually found their way back to the far-away countries where this substance was most readily harvested. People in these countries became rich beyond their wildest imagination. They raised their own powerful armies, then blackmailed, threatened, and destroyed neighboring governments who didn't approve of their appetite for power and riches.

But back in the once-strong country, things were taking a different course. The people had become irreversibly addicted to the substance. Every aspect of their lives revolved around it. It seemed to make life more bearable, but in fact it tended to make the people lazy, overweight, sloppy, and uncaring about their beautiful environment. Yet, they couldn't wean themselves from this terrible addiction.

The final chapter of this story is yet to be written. But there will not be a happy ending unless the people of this once strong and proud country wake up and take notice. They must overcome their seemingly unquenchable lust for this insidious substance. And what is this substance? Oil!

Roger S. Macomber
Professor of Chemistry
University of Cincinnati

Career choices

The recent discussions and proposals regarding the putative shortage of trained scientists available and "in the pipeline," gives one little optimism that things will improve much for the foreseeable future. The facts are that, relative to 20 or 30 years ago, science and scientists are not greatly valued either sociologically or economically in our society. Peer models for the young scientist (teachers, research scientists, etc.) are under tremendous pressure to produce, but often are given neither the time, financial resources, or environment to be creative and productive. Young people in the pipeline, often the brightest, see this and choose other fields that they perceive will provide greater opportunity for creativity that is rewarded.

Where to place the blame can be argued endlessly, but is unlikely to accomplish much. Until attitudes are changed, it is unlikely the career choices made by our best young people will change.

Victor J. Hruby
Department of Chemistry
University of Arizona, Tucson

California Proposition 128

Eric A. Anderson's letter (C&EN, Oct. 29, page 2) prompts me to write. He discussed the California ballot Proposition 128 ("Big Green"), with a pessimistic prediction of its passage, the poor outlook for the lot of chemical professionals in our state, and the difficulty California voters have in determining what the many ballot initiatives mean.

The situation he describes is largely in agreement with my own observations, but I feel he underestimates the power of the democratic process. The use of ballot initiatives to make laws has cer-

Correction

- Nov. 12, page 43: In the letter, "Replace chemical with compound," Robert L. Wolke's affiliation, the University of Pittsburgh, was inadvertently omitted.

Chemical Capital Spending Forecast To Slip in 1991

Stagnant chemical production coupled with increasing concern about a recession and inflation are taking their toll on spending plans

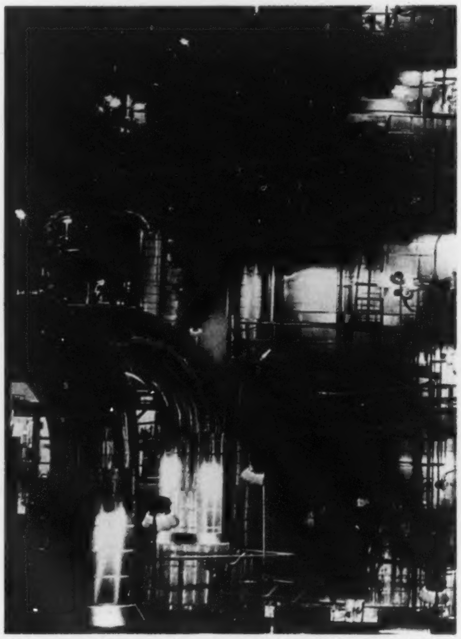
Marc S. Reisch,
C&EN Northeast News Bureau

Worldwide capital spending by major U.S. chemical producers will decline modestly in 1991, the first time spending has declined since 1986, according to preliminary forecasts by leading chemical companies.

For the eight chemical producers responding out of the 12 that C&EN surveys annually, 1991 capital expenditures will decline 3% from 1990 to a combined $7.39 billion. That forecast follows a hefty 17% increase in 1990 compared with the year earlier for reporting firms.

Last year at this time, chemical producers were still experiencing strong sales and earnings and had committed to a number of capital improvement projects. Despite predictions for an economic downturn in 1990, most chemical producers were predicting an increase in their capital expenditures for the year, often as part of a commitment to build new plants made during flush times.

Uncertain economic conditions make this the third year in a row when fewer than 11 companies have responded to C&EN's December survey. In 1987, 11 responded, but in 1988 only nine responded, and in 1989 eight responded. This year only eight responded again, but ironically, Du Pont's capital spending forecast is included in this year's survey, giving a much broader representation of industry trends. Du Pont's forecast has been missing for the past five years because the company's board of directors met too late in the month to approve release of the information. This year a new management structure allowed earlier release of the data.


Monsanto's recently expanded maleic anhydride unit at Pensacola, Fla.

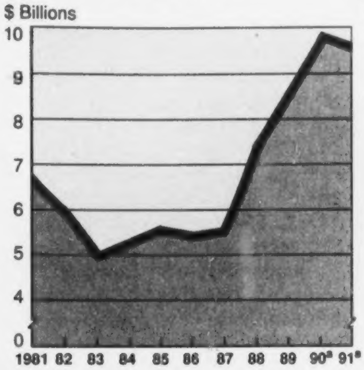
As a result, the forecast this year depends on responses from companies representing 70% of the total 1989 capital expenditures (the most recent year for which final expenditures are available for all 12 companies). Du Pont alone accounted for 30% of the capital expenditures of the 12 companies surveyed in 1989. In addition to Du Pont, the companies responding this year are Air Products & Chemicals, American Cyanamid, Dow Chemical, Ethyl, Hercules, PPG Industries, and Rohm & Haas. Missing this year are responses from W. R. Grace, Monsanto, Olin, and Union Carbide. Last year's survey depended on companies representing only 52% of 1989 capital expenditures (C&EN, Dec. 18, 1989, page 9).

Predictions for a decline in the capital spending plans in 1991 for individual companies are much more pronounced than the average decline of 3%. Rohm & Haas predicts capital expenditures will fall 26% in 1991 to $325 million, and PPG is not far behind with a 23% decrease. Hercules' plans call for a 14% decline in capital spending to $225 million. Du Pont plans a modest spending cut of only 2% from this year to $3.2 billion in 1991. On the positive side, only Ethyl predicts a double-digit increase, 23%, in capital spending to $185 million. Air Products plans a hike of 6% to $660 million, and Dow plans to raise spending only 3% to $2 billion.

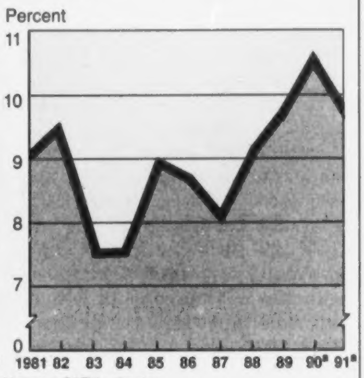
According to Du Pont's chief economist, Richard A. Stuckey, currently falling cash flow and concern about both a recession and inflation are not positive indicators for capital spending. Further, November declines in industrial production and a factory operating rate of 80% for industry, according to the latest government statistics, are "negative signals for prospective capital spending."

In his opinion, capital spending is likely to fall in 1991. About 30% of capital spending goes into building new structures, and contracts awarded for new structures have declined 25% compared with a year ago, he says. The worst is yet to come, he

Chemical capital spending to decline slightly . . .



. . . and slip as a percentage of sales



Note: Combined data from 12 major chemical producers listed below. a C&EN estimates.

adds, since capital spending has only begun to slip. He points out that capital expenditures are a lagging indicator because appropriations for new projects under way cannot simply be turned off.

But there is a silver lining in Stuckey's description of a gloomy capital spending picture. U.S. manufacturers are still taking a long-term view of their businesses. It is likely then that some capital projects, such as those for new plants and major expansions, will be pushed into 1992 or 1993. Projects that have the potential to give their owners good returns will not be canceled, only deferred, he says.

As for sales in 1991, Stuckey is projecting increases, but says they will be due mostly to the pricing of oil and strength in overseas sales of U.S. products. The price of oil will be the wild card, with much depending on what happens in the Middle East standoff between the U.S. and Iraq. Stuckey believes that the volume of chemical production in 1991 will actually fall several percentage points as a result of continuing weakness in the housing, automotive, and home furnishings industries.

Given the backlog of projects to which many chemical companies were committed in 1990, C&EN estimates that industry capital spending as a percentage of sales will weigh in at a hefty 10.7% in 1990. So far 1990 has been a year in which sales grew 10% in the first nine months for 30 major chemical companies (C&EN, Nov. 12, page 16), but also a year in which earnings declined 25% during the same period. In last year's survey, C&EN correctly predicted an increase in capital spending as a percentage of sales for 1990, but at 9.7% of sales understated the final number.

For 1991, C&EN estimates that companies still will spend a respectable 9.8% of sales on capital projects, based on the assumption that sales will grow at 7% in 1991 for the 12 firms surveyed. The high historical investment in capital improvements projected for 1991 seems to prove Stuckey's point that such spending is a lagging economic indicator.

In a recent survey of its membership, the Chemical Manufacturers Association predicted that the chemical industry will increase its capital expenditures 13% in 1991 from 1990, a finding very much at odds with C&EN's forecast of a 3% decrease based on its most recent survey. CMA estimates that capital expenditures for the chemical industry in 1990 rose 2% above 1989 spending—again in contrast to C&EN's forecast this year of a 17% increase based on responses from 11 of 12 companies in its survey.

Although overall 1991 capital ex-

Capital spending of surveyed companies will decrease 3% next year

	1991		1990		Worldwide					Change from previous year	
$ Millions	Total	U.S.	Total	U.S.	1990 planned[a]	1989	1988	1987	1986	1991	1990
Air Products[b]	$ 660	$ 440	$ 621	$ 342	$ 600	$ 414	$ 409	$ 323	$ 367	6%	50%
American Cyanamid[c]	370	270	370	270	na	398	374	268	263	0	−7
Dow Chemical	2000	1160	1950	1050	2100	1695	1670	995	890	3	15
Du Pont[d]	3170	2320	3220	2360	na	2563	2029	1674	1587	−2	26
Ethyl[e]	185	130	150	100	240	119	151	139	134	23	26
W. R. Grace	na	na	460	na	550	485	418	243	199	na	−5
Hercules	225	180	260	208	225	293	251	205	257	−14	−11
Monsanto	na	na	700	525	na	607	590	505	520	na	15
Olin	na	na	175	na	175	142	147	115	128	na	23
PPG Industries	450	300	585	390	450	537	410	426	356	−23	9
Rohm & Haas	325	240	440	320	395	385	338	222	179	−26	14
Union Carbide	na	na	na	na	na	785	671	502	524	na	na
TOTAL	**$7385**	**$5040**	**$8931**	**$5565**	**$4735**	**$8423**	**$7458**	**$5617**	**$5504**		
ANNUAL CHANGE[f]	−3%	0%	17%	5%		13%	33%	4%	−4%		

a Earliest estimate. b Fiscal year ends Sept. 30. c 1990 and 1991 exclude expenditures for Shulton Group, which has been sold. d Excludes Conoco. e 1989, 1990, and 1991 figures adjusted to reflect spin-off of Tredegar Industries in July 1989. f Cumulative change for companies reporting. **na** = not available.

German chemical giants boost U.S. spending

The three German chemical giants are so far unable to forecast their 1991 capital expenditure plans. Only one company last year, BASF, was able to make any predictions for the 1990 survey. However, the three companies can forecast their 1991 capital expenditures in the U.S. for the coming year, and as a group they plan to increase spending 10% to $1.3 billion.

Bayer plans the largest hike in the U.S. during 1991, with expenditures up 23% to $400 million. Meanwhile, Hoechst plans to spend $420 million in 1991, up 5% from its latest estimate of 1990 spending, and BASF will boost its U.S. expenditures 4% to $500 million. The increase in U.S. capital expenditures follows a much slower pace of annual increase in 1990 of 3%. For this year, Hoechst raised U.S. spending at its Hoechst Celanese unit 7% to $400 million, BASF increased spending 4% to $480 million, and Bayer decreased spending 2% to $325 million.

Collectively BASF and Bayer will have doled out $5.3 billion worldwide in 1990 on capital expenditures, according to their latest estimates. That level of expenditures marks a 35% increase over the 1989 level. Separately, BASF's 1990 spending level of $3 billion amounts to a 43% increase over 1989, and Bayer's $2.3 billion in 1990 spending is a 27% increase.

Compared with their U.S. counterparts who plan no increase in domestic capital spending, the German chemical giants will boost their spending in the U.S. in 1991 10%. If they elect to finance that investment with deutsche marks, they will be doing so with a much more favorable exchange rate. Last year C&EN used a conversion rate of $1.00 = 1.8 deutsche marks, an average conversion rate for 1989. This year, that conversion rate is $1.00 = 1.5 deutsche marks. That means that deutsche marks at this rate can buy 20% more U.S. dollars, and thus the German companies can actually spend fewer marks to do the work of more U.S. dollars. U.S. investment figures provided by the three companies surveyed in the U.S. were in U.S. dollars, while the worldwide numbers were quoted in deutsche marks and converted to U.S. dollars.

	1991		1990		Change from previous year	
$ Millions[a]	Total	U.S.	Total	U.S.	1991	1990
BASF	na	$ 500	$3000	$ 480	na	43%
Bayer	na	400	2333	325	na	27
Hoechst	na	420	na	400	na	na
TOTAL	na	$1320	$5333	$1205		
ANNUAL CHANGE[b]	na	10%	35%	3%		

[a] $1.00 = 1.5 deutsche marks. [b] Cumulative change for companies reporting. na = not available.

penditures likely will decline 3% in 1991 according to this survey, spending in the U.S. will remain unchanged for the group. Three of the eight who responded predict double-digit increases in their domestic spending in 1991 compared with 1990, in effect canceling out the decline in spending projected by the remaining six. Ethyl leads the group with a planned increase of 30% to $130 million in domestic capital spending, followed by Air Products with a projected increase of 29% to $440 million, and Dow with an estimated increase of 10% to $1.2 billion.

Those planning lower U.S. capital spending in 1991 are Rohm & Haas, down 25% to $240 million; PPG, down 23% to $300 million; Hercules, down 14% to $180 million; and Du Pont, down 2% to $2.3 billion. American Cyanamid predicts its 1991 domestic spending plans will remain unchanged from its 1990 expenditures of $270 million in the U.S. The 1990 and 1991 figures from American Cyanamid exclude spending for Shulton Group, which was sold during the past year.

Collectively, 1990 capital expenditures of 11 of the 12 companies responding to questions about this year's spending have risen to $8.9 billion, a 17% increase over combined spending by the group in 1989. Eight of the eleven predict that they will end the year spending considerably more than they had in the previous year. Air Products spent 50% more on capital improvements in 1990 with a total of $621 million. Du Pont and Ethyl both increased their expenditures 26%, with Du Pont's spending up to $3.2 billion and Ethyl's up to $150 million. Olin showed the next largest improvement, with capital expenditures up 23% to $175 million. Rohm & Haas also says it will end 1990 with a double-digit increase in capital expenditures, up 14% to $440 million, and PPG increased its spending 9% to $585 million.

Three of the 11 companies reporting for 1990 say they will end the year with a decrease in capital outlays. Hercules projects an 11% decrease to $260 million, and American Cyanamid, shorn of its Shulton Group, says it will have a decrease in capital outlays of 7%. Grace plans to end 1990 with a decline of 5% to $460 million.

As a measure of how plans change during the course of the year, only one of seven companies who gave C&EN its earlier estimate of capital spending for 1990 did not change its most recent 1990 spending account. Olin told C&EN that it planned to spend $175 million when first surveyed in 1989 and when surveyed again this month still maintained that it will spend that same amount. PPG's latest spending plans swelled 30% to $585 million, compared with its earlier estimated expenditures of $450 million. Hercules increased its spending plans 16% from its earlier estimates, and Rohm & Haas increased its spending total 11%.

Only two companies spent significantly less in 1990 than they originally planned. Ethyl first planned to spend some $240 million when it was surveyed a year ago, but it finally spent 38% less than that, at $150 million—still 26% more than it had spent during 1989. Dow also overestimated what it would spend in 1990 and now believes it will actually have spent 7% less than it planned for when first contacted a year ago.

Taken as a group, there is little discrepancy between the earliest spending plans and the most recent spending plans of the group. □

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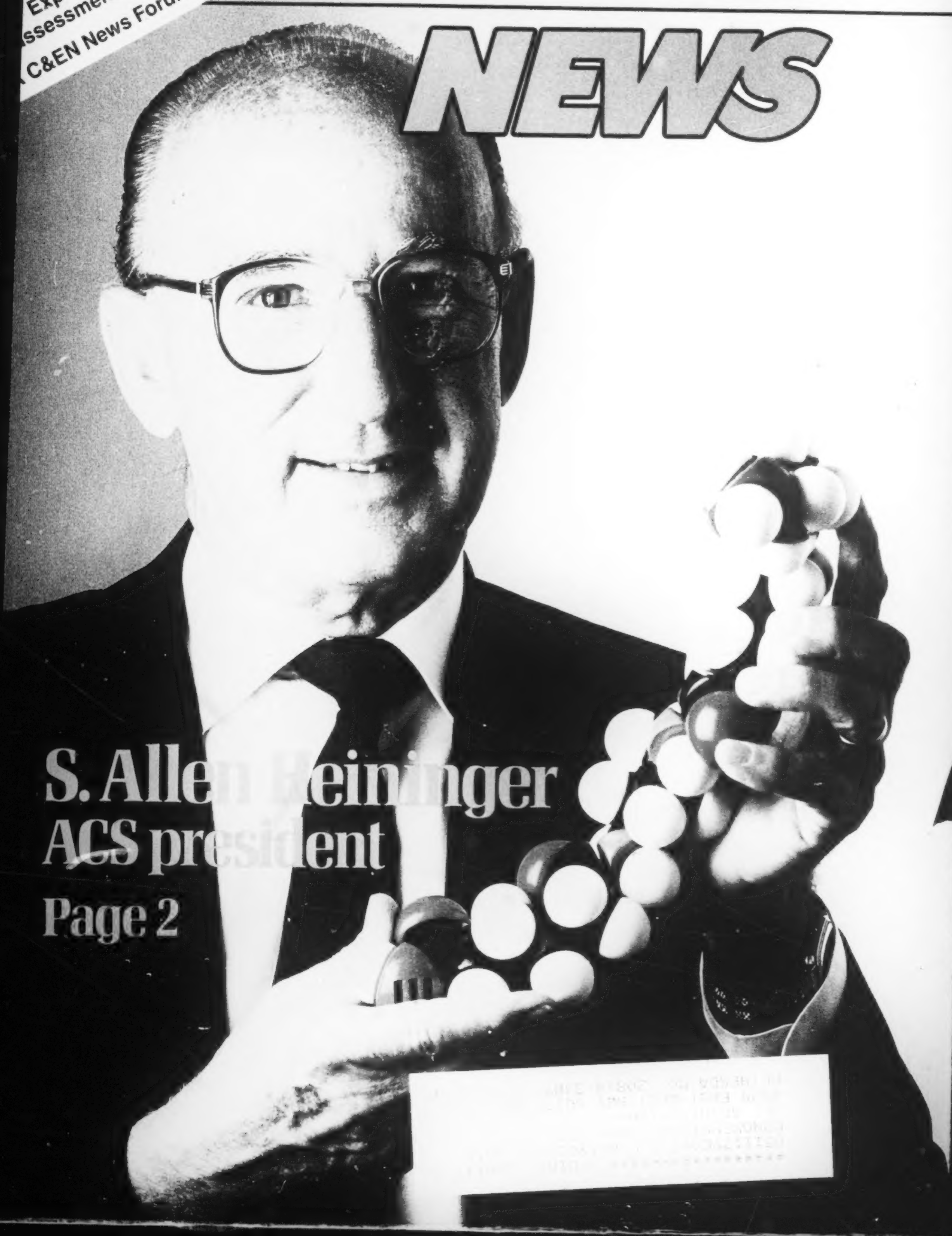
Experts debate risk
ssessment of pesticides
A C&EN News Forum Page 27



S. Allen Heininger
ACS president
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CHEMICAL & ENGINEERING
NEWS
JANUARY 7, 1991

Volume 69, Number 1
CENEAR 69 (1) 1–88
ISSN 0009-2347

News of the Week

- **Soviet economy and industry, including chemical industry, are in grim shape and will continue to disintegrate without rapid shift to a market economy, according to landmark study by major international economic organizations.** Page 6
- **Ozone hole over Antarctica could double in size in the future, according to a new analysis.** Page 7
- **A new program will enable industrial scientists to influence the direction of academic research on the theoretical simulation of molecular systems.** Page 7
- **Successful testing of genetically engineered factor VIII in more than 100 hemophiliacs offers great promise for hemophiliacs deficient in this blood clotting protein.** Page 8
- **Hercules' new chairman and chief executive officer, Thomas Gossage, initiates strategically significant organizational and management changes.** Page 8

Cover: Photo by Stephen Kennedy

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Business

British specialty chemicals producer MTM looks to 1991 for consolidating its diverse product mix following several years of rapid growth via acquisition. **Page 11**

Government

Union Carbide's two controversial Arizona chemical plants will soon begin operating as community protests over the plants' sitings and resultant delays wind down. **Page 15**

Science/Technology

Reducing engine emissions is a complicated problem, according to data gathered during a major testing program sponsored by oil firms and automakers. **Page 21**

New steam-explosion process designed to pulp a variety of paper wastes aims to eliminate municipalities' need to separate collected paper wastes. **Page 22**

Characterization of 2,4-dichlorophenol degradation pathway opens new possibilities for developing bioremediation strategies for chlorophenols. **Page 22**

Meetings

Deadlines and topics for ACS meetings in fall 1991, spring 1992, and later dates. **Page 59**

News Forum

Prominent figures representing five distinct viewpoints present their contrasting opinions on whether the risks from pesticides have been grossly exaggerated. Page 27

Chemistry, Society, and ACS

S. Allen Heininger
ACS president

As incoming president, it is my privilege to communicate to the membership of the American Chemical Society my personal views on the "State of the Society"—and what I see as the key things to be addressed in my presidential year.

The issues are many—from crises in science education to global climate change and the public perception of chemistry to lawsuits over intellectual property issues, plus a host of others.

Some relate to the science of chemistry itself, some to how chemistry interacts with the society in which we function, and some are internal to the operation and well-being of ACS as an organization. I'll address each in turn.

Fundamental to all, however, is the recognition that change is inherent in whatever we do. Our science of chemistry itself offers the best example of the continual evolution of knowledge. No chemist would dream of leaving school and try to earn a living using only the knowledge possessed at graduation. Continuing education is a must for any scientist—and continual change is equally a must for any scientific society striving to effectively serve the diverse needs of its members and its profession.

The changing world of chemistry

As our understanding of the world of chemistry around us extends into the life sciences through recombinant DNA and the frontier areas of protein chemistry and molecular biology, ACS must increasingly seek to establish common ground with those who have traditionally seen themselves as "natural scientists"—biologists, botanists, and so forth. Their understanding of natural evolutionary processes and phenomena, when coupled with chemistry's emerging tools of structural identification, synthesis, and engineering scaleup will unlock vast new opportunities to benefit mankind. As chemists, we must continually seek ways to facilitate the merging of the disciplines of science, since history demonstrates that it is at the periphery of separate knowledge bases that most discoveries are made.

To facilitate this process, with the leadership of the Committee on Science, an ACS presidential symposium on Expanding the Chemistry/Biology Interface is being planned for fall 1991. It will focus on the education of future scientists. Modern biology requires the integration of chemistry, computer science, engineering, applied math, and physics—in addition to biology itself. Educating future scientists into this complex of disciplines will necessitate thoughtful changes in how both chemistry and biology are taught in the 21st century. It is not too early to begin to think through how best to accomplish this.

> ***As chemists, we must continually seek ways to facilitate the merging of the disciplines of science***

On another frontier, the continued demands for higher performance materials create an equally complex problem. Materials science isn't yet an accepted discipline, but it is a broad frontier of change at which cutting-edge chemistry is demanded. New materials are required for space exploration, hypersonic flight, a broad range of defense needs, and to support the continued evolution of the electronics revolution itself. In the civilian sector, medical devices, high-performance materials for automotive use, metal alloys, ceramics, polymer composites, conductive polymers, and membranes for thin-layer separation systems all demand chemistry of the highest order of sophistication. ACS must find more effective ways to serve this materials science area—or risk losing the membership and involvement of a vital growth area of chemistry.

As chemists, we must avoid shackling ourselves to only what we learned in school, and the limits imposed by the traditional disciplines of chemistry. The entire periodic table is ours to employ for the benefit of society. As our knowledge grows, so must our vision of the future. While classical chemistry remains the bedrock foundation of our profession and must be nurtured and sustained, it must be capable of integrating with the concepts, methods, and advances of related sciences.

The demand for continued education is especially important for chemists employed in industry. Since they often toil in vineyards far from the academic frontiers, industry leadership must recognize the need to fight obsolescence of their work force. If industry is to avoid the redundancies and restructurings of the 1980s, with the inevitable human disruptions it created, providing constant opportunities for upgrading the skills of its scientists is a must. ACS through its continuing education short courses, its satellite TV presentations, national meetings, and publications offers a rich and expanding source of educational materials. This remains a major area of linkage between the academic and industrial members of ACS, and must be continually strengthened, especially through incorporation of modern videodisc and video-satellite techniques. Guidance from industry leaders on how to make ACS offerings most relevant to their foremost needs must be actively sought—and responded to.

SOVIET ECONOMY:
Study calls radical reform imperative

The Soviet Union's economy and industry—including its chemical industry—are in grim shape, and will continue to disintegrate without a rapid shift to a market economy, says an authoritative study just completed by four international economic organizations. A gradual reform program is bound to fail, it stresses. And without radical, comprehensive reform, it adds, large-scale western aid would be wasted and should not be given.

The study, probably the most thorough one yet of the Soviet economy by western economic institutions—with access to hitherto unavailable data—was commissioned at the Houston Economic Summit last July by the leaders of the seven major industrial democracies. It was carried out by the International Monetary Fund, the International Bank for Reconstruction & Development (World Bank), the Organization for Economic Cooperation & Development, and the European Bank for Reconstruction & Development.

The bleak picture the study paints is supported by recent statistics on Soviet industrial and chemical production. Through September, industrial production overall dropped 0.9% from the same period in 1989, according to the third-quarter plan fulfillment report by the U.S.S.R. State Committee on Statistics. And the United Nations Economic Commission for Europe projects a decrease of 1.5% for all 1990. The plan fulfillment report shows that gross national product decreased 1.5% compared with the first nine months of 1989, national income dropped 2.5%, and productivity of public labor fell 1.5%.

Soviet chemical industry—one of the fastest growing sectors in the 1970s and most of the 1980s—also fell 0.9% in output through September. Production of some key chemicals dropped much more, with sulfuric acid down 3%, sodium hydroxide down 7%, and synthetic ammonia and sodium carbonate down 8% each. For the first 11 months of 1990 and 1989, polyethylene output was down 3% and polypropylene 6%.

The plan fulfillment report notes that the shortfall in chemicals hinders development of other key sectors, including machine building, the agro-industrial complex, and consumer goods. More than half the chemical enterprises failed to meet their obligations to clients. Shortfalls in bulk plastics production (polystyrene and styrene copolymers, polyethylene, and polypropylene) created a shortage of raw materials for production of thermoplastic pipes and pipeline parts, output of which dropped 9%. Shortages were also created for polyethylene bags, and polymer barrels, trays, and boxes.

The study notes that "the traditional centrally planned system has largely collapsed, but has not been replaced by a functioning market system"—blocked by lack of a political consensus. Piecemeal reforms have failed to halt the decline, or have even been counterproductive. Indeed, the State Committee on Statistics cites "loss of the ability to control the national economy, the violation of economic ties, and the deterioration of labor and contractual discipline." Unemployment and monetary and financial imbalances are increasing. The overall balance of payments deficit in convertible currencies is projected at $14 billion for 1990. Oil and coal production are dropping. Open ethnic conflicts disrupt output and transport, republics increase their autonomy, and environmental concerns grow.

"The progressive breakdown is perhaps most visible at the retail level, with few goods to be found in state shops, barter becoming common, and black markets and the dollarization of the economy spreading rapidly," the study points out. Rationing is already widespread.

Soviet output of key chemicals plummeting

	% change	
	1988-89	1989-90[a]
Sulfuric acid	–3.6%	–3%
Sodium hydroxide	–4.2	–7
Synthetic ammonia	–7.9	–8
Sodium carbonate	–3.7	–8
Synthetic detergents	9.8	9
Mineral fertilizers	–7.5	–8[b]

a For January through September. b For January through November. Source: Plan Econ Inc.

Even if the Soviets adopt radical reform, things will get worse before they get better, the study says. But the West can aid greatly with technical assistance, humanitarian aid with food and other needs, programs in areas like the environment and energy, and financial aid.

The study jibes with a recent evaluation of Soviet chemical industry by PlanEcon Inc., a Washington, D.C.-based firm specializing in research on Soviet and East European economies (C&EN, Oct. 8, 1990, page 4). Jay K. Mitchell, manager of Soviet and East European chemical services at the firm, agrees radical reform is required. "It's long past the point of gradual reforms. Things are just splitting apart," he notes. But, he warns, "even if the central government adopts a radical reform program, it might not be able to get the republics to implement it now. The main problem now is the political instability caused by the economic problems. There is a real threat of dictatorship."

Richard Seltzer

JANUARY 14, 1991

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Congressional Outlook '91

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CHEMICAL & ENGINEERING
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Volume 69, Number 2
CENEAR 69 (2) 1–50
ISSN 0009-2347
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News of the Week

- **Utah's cold fusion research institute drops Pons and Fleischmann from its staff, but is requiring them to cooperate with a review group in verifying their experiments, or their funding will end.** **Page 4**
- **Outlook for the chemical industry in Western Europe this year is gloomy with demand slowing and production continuing to decline, according to recent U.K. Chemical Industries Association conference.** **Page 5**
- **Scientists express increasing concern about possible ecological disaster from any war in the Persian Gulf as mid-January deadline nears.** **Page 5**
- **Supreme Court denial of appeal by Dow and Shell in suit by Costa Rica workers over pesticide exposure means foreigners can sue the two companies in Texas courts.** **Page 6**

Cover: Photo by C&EN's David J. Hanson

Business

Canadian chemical firms strongly back new value-added tax that likely will make their chemical exports more competitive. **Page 17**

Arco Chemical has agreed to pay a record $3.48 million fine for alleged workplace violations leading to the explosion last summer at its Channelview, Tex., facility. **Page 18**

Government

Nobelist Leon Lederman's recent AAAS report on state of academic science and the need for higher funding touches off sharp dispute within science policy community. **Page 20**

Science/Technology

Sterically inducing conformational change in porphyrins promises way to vary electron-transfer rates in some basic reactions. **Page 23**

Two technetium-99m compounds for cardiac imaging that provide better quality pictures of the heart are approved by FDA for marketing. **Page 24**

Books

"Laboratory Health and Safety" covers wide range of subjects, some better than others; 4th edition of "Bretherick's Handbook of Reactive Chemical Hazards" is a comprehensive, valuable tool. **Page 26**

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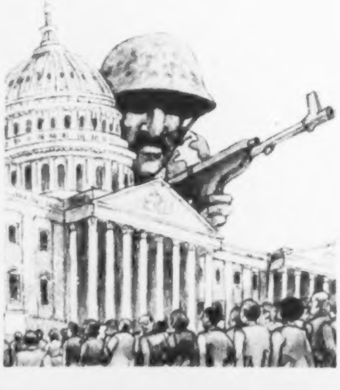

News Focus

The specter of fighting in the Middle East dominates the 102nd Congress' discussions despite an agenda that includes energy, environmental, science ethics, and global change issues **Page 10**

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1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John K Crum, Executive Director
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Subscription Rates 1991. Printed editions: nonmembers U.S. 1 yr. $95, 2 yr. $171; outside U.S. 1 yr. $131, 2 yr. $243. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $12. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

CHEMICAL SAFETY

Treatment for eye irritants

Ronald C. Moyer described an unexpected ocular reaction to exposure to isopropyldiimide (C&EN, Nov. 5, 1990, page 2). The injuries he described, in type, duration, development, and recovery, are identical to standard descriptions of mild to moderate mustard gas injuries. The molecular mechanism of mustard gas is alkylation of nucleophilic functional groups of intracellular components, especially the guanine on DNA, which occurs within minutes of exposure. The affected cells are unable to function and reproduce and die off, causing the symptoms. No treatment, except immediate washing off of the chemical and supportive care until the wounds heal, is possible.

In view of their chemistry and these observed biological effects, it is reasonable to assume that all alkyldiimides are capable of functioning as alkylating agents and are therefore vesicants and carcinogens. Users of these chemicals should avoid all contact by using glove boxes, fume hoods, full-face respirators, and similar means. If exposed, the usual washing off of affected surfaces, skin and eye, will minimize injury if started quickly enough.

For more details on this sort of injury and its treatment, the experts are the Army Medical Research Institute on Chemical Defense (USAMRICD), Aberdeen Proving Ground, Md. 21010-5425, and open publications such as their Technical Memorandum 90-1, "Clinical Notes on Chemical Casualty Care," and "Treatment of Chemical Agent Casualties and Conventional Military Chemical Injuries," Army TM 8-285, Navy NAVMED P-5041, Air Force AFM 160-11.

Harry V. Ellis III
Toxicologist, PRC Environmental Management Inc., Chicago

Japan's biotechnology

In Bernard Wolnak's letter commenting on Japanese biotechnology (C&EN, Oct. 15, page 5), he cites reasons for their nonsuccess to date. At present, the U.S. leads the world in basic research and money spent on R&D. We are the prime source of products and technology in this neonatal field. This should not be considered "U.S. domination in the marketplace," as Wolnak put it, since few of the potential products of biotechnology have reached the marketplace. I offer, however, the following points as indicators of Japan's potential success.

- Biotech consumer products already reach large markets in Japan—biodetergent, biolipstick, and biowines. These prime their public as to the benefits of biotechnology with products they wash their clothes in, paint on their lips, and ingest. The awareness that biotech is good and is all around us has not occurred in the U.S.
- The San-Gaku-Kan interactions are indicative of good communications among the key players in Japan. In the U.S., we don't enjoy these good communications to the same degree. As an example, our recent survey of 242 U.S. biotech firms cited the Food & Drug Administration as their largest barrier to success.
- The coordination of technology development by MITI and other Japanese government agencies is likely overrated, but these programs do serve as catalysts to get companies working with technologies they might have otherwise bypassed. They have also served to get some fresh blood in mature industries, such as Kirin entering pharmaceuticals through biotechnology.
- The U.S. is still the greatest source of basic research in biotechnology, with about $3 billion spent on biotechnology R&D by the government. However, Japanese companies have ready access to the basic technologies and products via strategic alliances with U.S. companies. Their managers still point to U.S. biotech firms as sources of many of their biotech products. R&D is expensive, and the Japanese have been able to cut costs by licensing promising products at a fraction of the costs that U.S. companies incur to produce their own. And, the Japanese companies have bypassed much of the expense of basic research and wasted costs of failed product development.
- The Japanese biotechnolgy industry is primarily made of large corporations, many of which have the capital to play this expensive game and many with a strong history of succeeding in their industry both locally and globally. Their culture fosters methods to share or reduce risk. The majority of the U.S. play-

Electric Power Research Institute and the Department of Energy, saying "we will vigorously pursue" such funding.

Regardless of what happens to the institute, Will asserts that the conference series that was inaugurated there last year will continue. In June, the second annual cold fusion conference will convene in Italy. That country is perhaps the most fitting venue since it is, as far as Will knows, the only place in the world where researchers have observed the production of excess heat, tritium, and neutrons in the same experiment. Unfortunately, it's not reproducible.

Ron Dagani

West Europe chemicals face gloomy 1991

A gloomy picture of Western Europe's economy was painted last week at the annual Business Outlook Conference of the U.K. Chemical Industries Association (CIA). Some nations are moving into a recession or are already there, and others show slowing demand, which eventually will mean less chemical production required.

In 1990, chemical output in Western Europe rose barely 2% over that in 1989, less than the growth of manufacturing overall, reports Richard Freeman, chief economist at ICI and chairman of the economic outlook committees of both CIA and the European Chemical Industry Federation. For 1991, he expects chemical growth of 2% again, while overall manufacturing grows more slowly. However, war in the Persian Gulf could wreck such predictions.

In the U.K., chemical production will continue to decline in 1991, dropping 1% from 1990, which in turn was down 0.6% from 1989. Current forecasts for the other countries, Freeman adds, may be somewhat overoptimistic, except for the German chemical industry. "Germany is the locomotive which is pulling the rest of Europe along," he notes, fueled by the need to supply the newly consolidated eastern part of the country. In fact, German chemical industry cannot supply all the demand, necessitating imports from other European countries, especially France—in turn, requiring higher production by them.

However, there will be a limit to that extra demand and production. And as domestic economies slow, causing a slowdown in imports, competition will intensify for potential exports. Further competition will come from the U.S., with the weak dollar making U.S. prices relatively low. Freeman believes the optimistic forecasts assume too much strength in the export market: "Where are all those exports going to go?"

For the U.K. in 1991, Freeman's CIA panel predicts growth only for production of pharmaceuticals (up 3%). For detergents, cosmetics and perfumes, and fibers, output will remain about the same as in 1990, while other sectors will show losses. The most severe drop—4%—will come in organics, plastics, and dyes. Organics and dyes also fell in 1990.

For other West European countries, widely varying performances are projected for different chemical sectors. However, aggregate forecasts are more positive than for the U.K.—particularly welcome for organics and plastics. For example, only Italian producers expect a further fall in organics. For all Western Europe, the fall of 2% in plastics production in 1990 will be reversed this year, to show growth of about 2.5%. Fibers output is expected to be flat, as is that of the troubled fertilizer sector.

As for capital investment, with both production and demand weakening, and substantially reduced profits in 1990, firms are cutting investment plans everywhere, Freeman notes. "Total investment in Western Europe, including the U.K., is forecast to be unchanged in 1991 after rising by nearly 8% in 1990." However, he adds, his panel would not be surprised if investment were cut even more.

This comment led to a warning against over-hasty cutbacks from Robert Malpas, recently retired chairman of BP Chemicals and now a director of London-based merchant bankers, Baring Brothers. "Now is the time to make sure every single investment that can be justified, for energy efficiency, process yield improvement, and so on, is made," he stresses. "If these investments are cut back now, it will only delay getting true productivity gains."

Patricia Layman

European chemical output may slow next year

	% change	
	1990–91[a]	1991–92[b]
Belgium	5.5 %	4.0%
France	1.25	2.5
Germany[c]	2.0	2.0
Netherlands	1.5	2.0
Italy	1.5	0.4
Spain	3.5	3.0
U.K.	–0.6	–1.0
TOTAL WESTERN EUROPE	**2.0 %**	**2.0%**

a Estimated. b Forecast. c Western German chemical industry only. **Source:** Individual countries' chemical industry associations

Scientists say Gulf war could devastate ecology

The long-term environmental costs of war in the Persian Gulf are "likely to outstrip all other costs, great though those will be," claim Paul Crutzen, an atmospheric chemist and director of the Max Planck Institute in Germany, and several other well-respected scientists.

They sounded this warning at press conferences in London on Jan. 2 and in New York last Friday, at which they announced formation of an international scientific task force. The task force would act as an environmental crisis management network, deployed swiftly to advise political leaders in the early days of future crises, explains physicist Abdullah Toukan, chief scientific adviser to King Hussein of Jordan.

The scientists' fear of ecological disaster is based on the assumption that Iraqi President Saddam Hussein will detonate the Kuwaiti oil wells some military strategists say he has mined. Such detonations could set ablaze up to 1000 oil wells and burn about 3 million barrels of oil per day, estimates John Cox, a British chemical engineer and independent consultant to an oil company operating in the Persian Gulf. It could take

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Companies plan slight increase
in R&D spending this year Page 11

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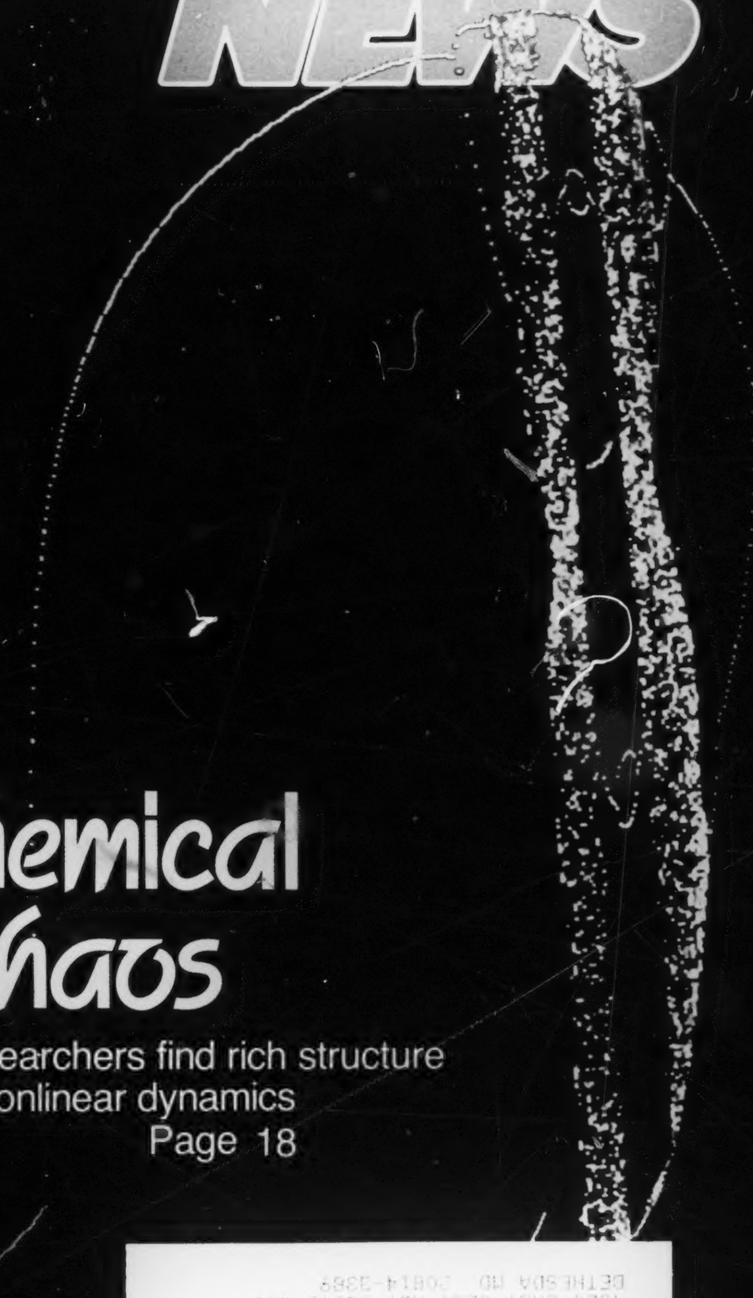

Chemical Chaos

Researchers find rich structure
in nonlinear dynamics
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ISSN 0009-2347

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JANUARY 21, 1991

News of the Week

- **Chemical and oil companies ready themselves for effects that the war in the Middle East will have on industry.** Page 4
- **Suit seeks to block planned use of drugs lacking FDA approval on U.S. troops without their informed consent.** Page 4
- **A number of prominent scientists join together to decry armed intervention in the Middle East.** Page 5
- **Occidental Petroleum's new chief announces major restructuring in effort to carve $3 billion from its long-term debt.** Page 5
- **FDA cuts its average drug review time nearly five months to 27.7 months, but this is still far from the six-month statutory standard.** Page 6

Cover: Oscillatory reaction model shows period doubling leading to chaos (vertical bands) and subsequent return to periodic behavior. Calculation and photo by Bo Peng and Kenneth Showalter, West Virginia University

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Business

Major U.S. chemical firms plan only 3% increase in R&D spending on average this year, in contrast to 8% in 1990, according to a recent C&EN survey. Page 11

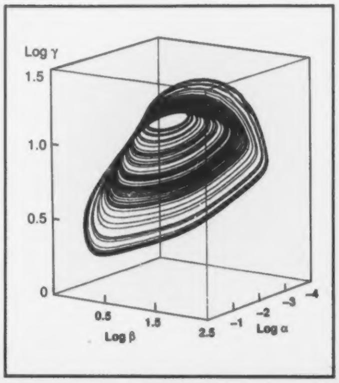
Government

EPA finally issues drinking water standards for 38 more contaminants, and estimates cost of compliance by drinking water systems at a combined $88 million a year. Page 15

State precursor laws are proving very effective in curbing illegal drug making, but they have led to additional paperwork and reporting responsibilities for companies and laboratories. Page 16

Meetings

Calendar of meetings and events is semiannual listing of interest to chemists and chemical engineers. Page 41



Science/Technology

Investigating chaotic chemical systems—ones that oscillate in concentration, potential, or another parameter—provides researchers with glimpses of ordered structure in systems previously thought inscrutable. Page 18

Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

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Published by
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Subscription Rates 1991. Printed editions: nonmembers U.S. 1 yr. $95, 2 yr. $171; outside U.S. 1 yr. $131, 2 yr. $243. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $12. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

CHEMICAL SAFETY

Rash from ruthenium complex

Two investigators in our laboratory have displayed an extreme sensitivity to [$RuCl(PMe_3)_2(Cp)$]. When handling the substance using normal benchtop Schlenk techniques, both developed severe rashes on exposed areas of the skin, especially on the face. We recommend that this compound be stored and handled in a glove box.

[$RuCl(PMe_3)_2(Cp)$] was prepared from [$RuCl(PPh_3)_2(Cp)$] and PMe_3 following published procedures [Bruce, M. I., Wong, F. S., Skelton, B. W., White, A. H., *J. Chem. Soc., Dalton Trans.*, 1398 (1981); Treichel, P. M., Komar, D. A., *Synth. Inorg. Met.-Org. Chem.*, **10**, 205 (1980)]. Neither of the starting materials produced a similar physiological reaction, nor did derivatives with PMe_2Ph, dppe, or $P(OMe)_3$ ligands.

John P. Selegue
George A. Koutantonis
Jeffrey R. Lomprey
University of Kentucky
Lexington

Biomass research

The letter on biomass research (C&EN, Nov. 19, 1990, page 2) reminds me of my experience in using wastes. About 1932, A. O. Smith Co. of Milwaukee, wanted to build prefabricated houses that were to sell for $3000, erected. They assigned to their research department the task of developing a material that could be fabricated into shapes required for the structure of prefabricated houses, and set a target cost per square foot of surface. The target cost was so low that the research group decided that only waste materials could be used, and a corrugated or hexagonal structure would be required, which meant a sheetlike material. The research group selected waste liquor from a paper mill and waste paper as the possible raw materials. The initial waste liquor used was the waste from a sulfite process paper mill.

A. O. Smith dropped that project, but it was carried on by a sulfite paper mill. A plant was built to produce the pulp, using waste wood and the sulfite waste liquor. It was run on the paper machine and pressed into panels. The pulp was also used to make phenolic molding compounds. At one time, this material was presented to Ford Motor Co., and Henry Ford came to that meeting and asked if the material could be pressed into a trunk door and withstand the blow of a sledgehammer. The answer had to be "no" to the blow from the sledgehammer. It was unfortunate that I did not know of Ford's interest in biomass products, for this was a biomass product.

Research was continued on the process. Instead of using the waste from a sulfite paper mill, black liquor was used from a kraft paper mill. The pulp was run on a small paper machine and the paper sheets were laminated. This laminated panel and a commercial phenolic laminate were tested using the standard testing procedure for this type of product. The specific gravity and the water absorption of the two panels were the same. The lignin laminate had 10% higher flexural and tensile strength and five times the resistance to impact compared to the phenolic sample. This lignin sample would have shown up much better in Ford's sledgehammer test.

The low cost of the waste raw materials, the availability of the high tonnage of both, and the use of this type of panel in the building industry show interesting possibilities. However, from the biomass research point of view, the organic chemicals in the black liquor are still in the waste liquor of this process and may be recovered more economically because of the absence of the lignin.

John G. Meiler
Cleveland, Tenn.

Lithium perchlorate solvent

In response to Baldur Föhlisch's letter (C&EN, Nov. 19, 1990, page 2) concerning the use of 5.0M lithium perchlorate in diethyl ether as a solvent for the Diels-Alder reaction, I believe it is appropriate to get the facts correct. Lithium perchlorate solutions in diethyl ether have been employed extensively over the years to accelerate reactions with polarized transition states. Over 30 years ago, Saul Winstein [*J. Am. Chem. Soc.*, **81**, 5111 (1959)] observed that the ionization rate of

Chemical Industry R & D Spending To Increase Modestly

Ten major chemical producers plan 3% hike in research expenditures this year, translating to only a 1% rise in constant-dollar terms

Marc S. Reisch,
C&EN Northeast News Bureau

Most major U.S. chemical and diversified companies plan to increase research and development spending in 1991, but at a slower pace than last year. C&EN's just-completed survey of 14 chemical companies shows that the 10 who did supply figures plan to increase R&D spending this year an average of only 3% over last year. According to the same survey, the 14 companies' most recent accounting estimates show that their R&D spending in 1990 increased an average of 8% over 1989.

The 3% increase for 1991 found in this survey agrees closely with Battelle Columbus Laboratories' just-released estimate of a 3.5% rise for all industry. Battelle bases its forecast on data drawn from National Science Foundation reports, federal budget documents, and other sources. The Columbus, Ohio-based technology organization projects total 1991 R&D spending by all U.S. industry will reach $155 billion, including that financed by government.

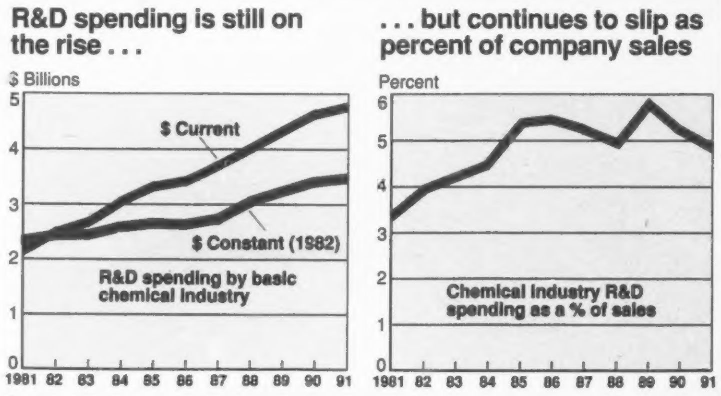
Battelle notes, however, that the real increase in R&D spending this year will be only 1% after factoring in inflation, which it estimates at 2.4% for 1991. Using Battelle's figure for R&D inflation to estimate this year's constant-dollar expenditures for the 10 chemical companies in C&EN's survey also yields only a 1% real increase.

Battelle finds that the growth rate of domestic R&D expenditures has been slowing and is expected to continue in a period of uncertainty. For one, Battelle notes that decreases in defense procurement and the resulting profits will affect the availability of funds for R&D in some industries. Meanwhile, the nation's trade imbalance and efforts to correct it, along with efforts to expand some markets in response to shifts in government priorities, could lift R&D spending.

But Battelle continues to lament industry's overall emphasis in support of short-term R&D projects that seek short-term financial results rather than technical innovation. That trend will continue to have an adverse effect on the quality of R&D and amount of industry's investment in it, Battelle predicts.

In the past few years, chemical companies have generally increased R&D spending at a much higher rate than all industry. In 1989, for example, C&EN found that the chemical companies it surveyed spent 8% more in 1989 than 1988, and Battelle forecast only a 3.4% increase for all industry that year (the latest data available). Still, it is important to note that the chemical industry continues to spend a much higher percentage of its sales on R&D (close to 6% in 1989 and almost 5% estimated in 1991) than industry as a whole (about 1.6% in 1989 based on C&EN estimates and the most recent Federal Reserve Board estimates).

The Chemical Manufacturers Association's recent poll of its membership shows that respondents plan to increase spending 5.5% in 1991 over 1990 levels. Since CMA's membership comprises both chemical and diversified companies, that estimate dovetails nicely with C&EN's survey results, in that it is midway between the 3% for chemical companies in C&EN's survey and 8% for the four diversified chemical producers who supplied projections of 1991 spending. Similarly, CMA's survey shows that members' R&D spending grew 9.1% in 1990, a little higher than the 8% that C&EN's survey found for chemical companies and much higher than the 3% growth for eight diversified companies that responded.



Note: For 14 chemical companies listed on page 13.
Sources: C&EN surveys and estimates, Battelle Columbus Laboratories

One difference in this year's C&EN survey and previous years' is the addition of two companies to the list of chemical firms surveyed—Lubrizol and Petrolite—and also the addition of two diversified companies—AT&T Bell Labs and Procter & Gamble. They have been included in an effort to broaden the survey. C&EN had hoped to include General Electric and IBM as well, but they couldn't estimate either 1990 R&D spending or 1991 plans at the time of the survey.

If IBM and General Electric were included in the survey, they would significantly expand the monetary pool on which R&D estimates for diversified companies are based. IBM, for instance, states in its 1989 annual report that it spent $5.2 billion on company-financed R&D that year, which was 8.3% of sales. General Electric says in its 1989 annual report that it devoted $1.3 billion to company-financed R&D efforts that year, which amounted to only 2.4% of sales. Both companies increased R&D spending substantially in 1989. IBM raised its spending almost 18% from 1988, following an 11% rise the previous year. And GE increased its R&D spending in 1989 16% from the previous year, following a 4% decline in 1988.

A number of foreign-owned firms also conduct a significant amount of chemical R&D in the U.S. but are not included in C&EN's tabulation. Until two years ago, SmithKline Beckman Corp. was regularly included in C&EN's annual survey of R&D spending. But with the 1989 merger with U.K.-based Beecham Group, to form SmithKline Beecham, the company now reports its figures in British sterling, although the bulk of the new company's research effort is still in the U.S. Currency translations can significantly alter the increase or decrease in budgets. Although the company reports it invested £390 million in R&D in 1990 and company sources assume it will spend the same amount in 1991, the British pound has appreciated 15% during the past year, swelling the dollar budget by a like amount.

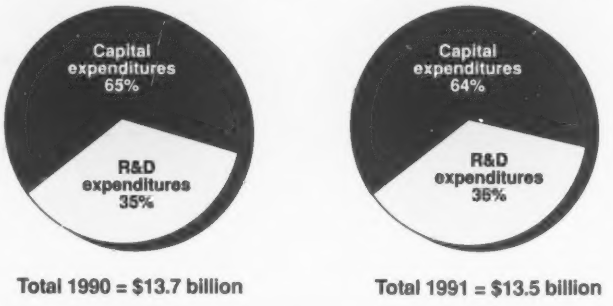
German chemical companies with major investments in the U.S. will continue to benefit from the effects of currency appreciation (up 10% during 1990) when they exchange deutsche marks to pay for research undertaken in the U.S. Bayer Group says it increased its R&D worldwide from 2.7 billion deutsche marks in 1989 to 2.8 billion in 1990—a 3.6% increase.

Hoechst boosted its R&D spending 7.7% in 1990 to 2.8 billion deutsche marks, the same budget as Bayer. According to Utz-Hellmuth Felcht, vice president of Hoechst Celanese and president of its advanced technology group, the 1991 budget worldwide will probably rise only enough to adjust for inflation and salary cost increases.

In the U.S., Hoechst Celanese will increase its R&D budget from $244 million in 1990 to $255 million in 1991 in support of the life sciences, high-performance polymers, and technical fibers and films that are the major focus of the advanced technology group. This roughly 5% increase follows an almost 10% yearly increase in 1990 and is meant to add the cost of inflation and salary cost increases to the budget while still giving U.S. operations a "modest growth and a safety net," says Felcht. The company will continue its efforts, he adds, to recruit new scientists from universities at the same level as last year. "The worst thing you can do is to hire in good years and stop in bad years, because you lose your reputation for reliability."

Phillips 66 technician inspects K-Resin butadiene-styrene copolymer samples made at new pilot plant at R&D center

R&D inches up as percent of future-oriented spending



Note: Based on C&EN surveys and estimates of 12 major chemical companies listed on page 13 (Petrolite and Lubrizol are excluded because they were not included in the 1991 capital spending survey).

Among specific chemical companies in this year's C&EN survey, Air Products & Chemicals plans the biggest increase in R&D spending with a 9.7% rise from 1990 to $79 million. The 1991 increase follows a 1.4% increase the year before. W. R. Grace plans the second biggest gain in 1991, with its R&D funding rising 7.1% to $150 million. That increase follows a 12% rise the year before when the company figures it spent $140 million on R&D.

PPG Industries has budgeted moderate growth for its R&D spending in 1991 with a hike of 6.4% planned to $250 million. This follows about a 1% increase in 1990 to $235 million. Union Carbide plans to raise its R&D spending 5.3% in 1991 to $200 million after increasing its spending 5% last year.

Both American Cyanamid and

Major chemical companies plan 3% increase in R&D spending this year

									Change from previous year		R&D spending as % of sales	
$ Millions	Planned 1991	Actual 1990	Planned 1990	1989	1988	1987	1986	1985	1991	1990	1991	1990
CHEMICAL COMPANIES												
Air Products[a]	$ 79	$ 72	$ 71	$ 71	$ 72	$ 57	$ 61	$ 51	9.7%	1.4%	2.6%	2.5%
American Cyanamid	479	458	450	406	365	314	278	251	4.6	12.8	9.0	9.2
Dow Chemical	1180	1150	950	873	772	670	605	547	2.6	31.7	6.1	6.3
Du Pont[b]	1220	1350	1380	1387	1319	1223	1156	1144	−9.6	−2.7	5.2	6.1
Ethyl[c]	68	65	65	61	59	50	47	47	4.6	6.6	4.1	4.2
W. R. Grace	150	140	145	125	119	107	94	92	7.1	12.0	2.2	2.2
Hercules	na	89	na	79	74	74	71	76	na	12.7	na	2.8
Lubrizol	na	73	na	70	65	62	51	44	na	4.3	na	5.8
Monsanto	na	625	na	598	575	557	523	470	na	4.5	na	7.0
Olin	na	65	65	66	58	62	56	53	na	−1.5	na	2.5
Petrolite	12	12	na	12	12	12	12	12	0	0	3.7	4.0
PPG Industries	250	235	250	233	227	227	204	176	6.4	0.9	4.0	4.0
Rohm & Haas	185	180	180	175	156	142	133	124	2.8	2.9	6.3	6.6
Union Carbide	200	190	na	181	159	159	148	275	5.3	5.0	2.1	2.1
TOTAL	**$3823**	**$4704**	**$3556**	**$4337**	**$4032**	**$3716**	**$3439**	**$3362**			**4.8%**	**5.2%**
ANNUAL CHANGE[d]	**3%**	**8%**		**8%**	**9%**	**8%**	**2%**	**10%**				
DIVERSIFIED COMPANIES												
Allied-Signal[e]	700	700	650	603	647	400	360	298	0	16.1	5.3	5.7
Arco Chemical	na	na	na	52	39	29	32	29	na	na	na	na
AT&T Bell Labs	na	2400	na	2652	2572	2453	na	na	na	−9.5	na	6.5
Eli Lilly	na	700	na	605	500	466	427	370	na	15.7	na	16.3
FMC	140	158	155	150	144	132	146	149	−11.4	5.3	3.7	4.5
Merck & Co.	na	855	na	751	650	566	480	426	na	13.8	na	12.7
Morton International[e,f]	60	48	50	38	35	31	29	na	25.0	26.3	3.9	3.3
Procter & Gamble[e,g]	na	693	na	628	615	549	479	na	na	10.4	na	2.8
Schering-Plough	420	370	370	327	298	251	212	189	13.5	13.1	12.1	11.4
TOTAL	**$1320**	**$5924**	**$1225**	**$5806**	**$5500**	**$4877**	**$2165**	**$1461**			**6.0%**	**6.3%**
ANNUAL CHANGE	**8%**	**3%**		**6%**	**13%**	**12%**	**13%**	**11%**				

a For fiscal year ended Sept. 30. **b** All figures exclude Conoco. **c** 1989, 1990, and 1991 figures adjusted to reflect spin-off of Tredegar Industries in July 1989. **d** For those companies reporting. **e** Includes all company-financed R&D, but excludes contract R&D. **f** Fiscal year ended June 30. Figures adjusted to 1986 in order to reflect division of Morton Thiokol into Morton International and Thiokol Corp. in July 1989; 1985 figures are for Morton Thiokol. **g** Fiscal year ended June 30. **na** = not available.

Ethyl plan 4.6% increases in their R&D spending levels in 1991. Cyanamid plans to boost its spending to $479 million following a 13% increase the previous year. The Cyanamid figures for 1991 exclude spending for Shulton Group, which Cyanamid sold during 1990. About $30 million of the 1990 R&D budget involved spending for Shulton Group. Ethyl's planned 1991 increase in R&D expenditures to $68 million follows a 6.6% increase the previous year.

Several companies fell below the average increase for the 10 chemical companies that supplied 1991 figures. Rohm & Haas plans to increase R&D spending 2.8% this year to $185 million, following a 2.9% increase last year. Dow Chemical plans only a modest increase of 2.6% in 1991 to $1.2 billion, following a 32% increase last year. Petrolite's R&D budget will remain unchanged in 1991, frozen at the same level since 1984.

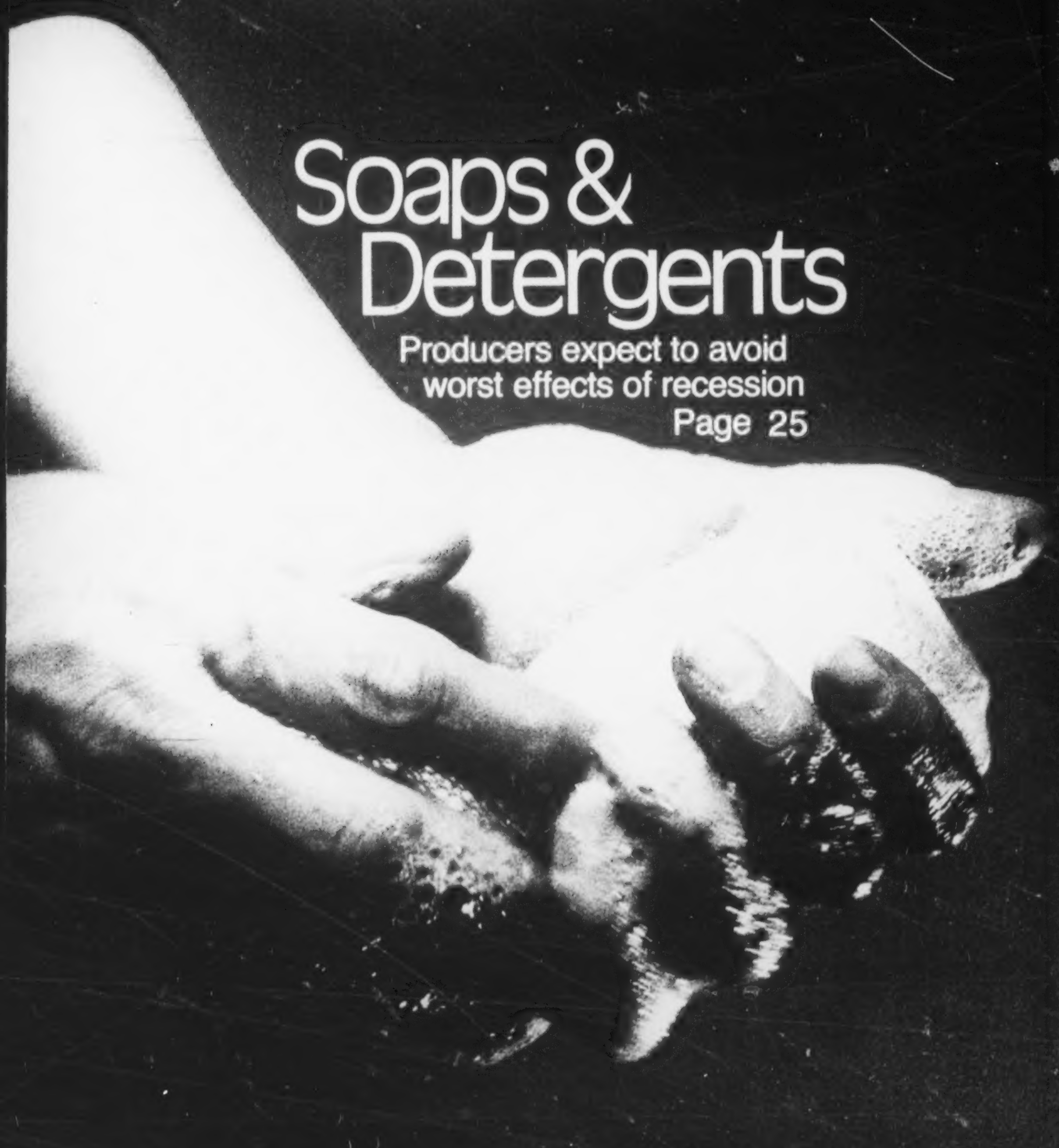
Du Pont has budgeted a significant decrease in its R&D spending for 1991. The company plans to spend $1.2 billion, down a hefty 9.6% from last year. This decline follows a smaller 2.7% drop in spending last year.

Hercules, Lubrizol, Monsanto, and Olin were unable to provide an early estimate of their R&D spending for 1991. However, all three supplied estimates of their 1990 spending. Hercules' 1990 R&D spending rose 13% from 1989 to $89 million. Monsanto increased its 1990 spending 4.5% to $625 million, and Lubrizol boosted its spending 4.3% to $73 million. Olin, however, reported a net decline in 1990 R&D spending to $65 million.

Among chemically related diversified companies, four providing 1991 spending estimates—Allied-Signal, FMC, Morton International, and Schering-Plough—plan to increase their R&D budgets an average of 8% this year. Their figures include internally generated R&D projects only and not government contracts. Of the four, Morton International plans the largest increase: 25% to $60 million, following a 26% increase in 1990. Schering-Plough, the pharmaceuticals manufacturer, plans the second largest increase among the four, 14% to $420 million, following a 13% increase in 1990. ☐

JANUARY 28, 1991

CHEMICAL & ENGINEERING NEWS



Soaps & Detergents

Producers expect to avoid worst effects of recession

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CHEMICAL & ENGINEERING
NEWS
JANUARY 28, 1991

Volume 69, Number 4
CENEAR 69 (4) 1–76
ISSN 0009-2347

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- **Cancer risk of exposure to dioxin may be lower than previously thought, according to new epidemiologic study from NIOSH on industrial workers exposed to high levels of dioxin.** Page 7
- **Last year's fourth-quarter earnings of many chemical companies are down or flat, reflecting decline in economy.** Page 7
- **Exxon and Monsanto have merged their thermoplastic elastomer businesses to form a new firm, Advanced Elastomer Systems, with estimated worldwide sales of $100 million.** Page 8
- **Belgian chemists develop nonporous aromatization catalyst for *n*-alkanes that may offer new approach for hydrocarbon re-forming.** Page 8

Cover: Photo by Amy Meyer Phifer

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Business

Process for "clean" reformulated gasoline, ready for licensing to refiners, promises increased engine efficiency, lowered emissions. **Page 11**

German agency is seeking foreign funds for plan to remodel former East German firms into competitive, free-market institutions. **Page 12**

Government

New safety standards expected this year for railroad cars carrying hazardous materials are aimed at improving design and safety features of tankcars. **Page 16**

Science/Technology

Stable, crystalline carbene is isolated by Du Pont researchers, but French chemist, whose work they didn't cite, disputes their claim of first "bottle-able" carbene. **Page 19**

NASA and European Space Agency plan joint Saturn mission to begin in 1996 or earlier. **Page 20**

Quantized transition state is revealed by highly accurate quantum dynamics calculations. **Page 21**

Catalytic, low-temperature, solution-phase oxidation of methane to methanol derivative achieved. **Page 22**

Books

One hundred-plus year history of the chemistry department at the University of Wisconsin, Madison, is a model par excellence; "Readings in Risk" gives readers several viewpoints. **Page 54**

Product Report

Soap and detergent producers look for sales to rise more than 3% this year on the strength of new formulations, more innovative products, and expanding research in spite of the specter of recession. **Page 25**

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Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

CHEMICAL SAFETY

Synthesis of nopinone

Letters to C&EN (Aug. 6, 1990, page 2; Dec. 10, 1990, page 4) have described the hazards associated with the ozonolysis of β-pinene to produce nopinone. While at Purdue University, my colleagues and I successfully ran this reaction several times (up to a 0.5-mole scale; 85% yield) using a Me_2S quench (sixfold excess for 36 hours at ambient temperature).

Recognizing the inherent dangers of this methodology, we developed a simple, alternative synthesis of nopinone, the full experimental details of which can be found in the *Journal of Organic Chemistry* [**55**, 1220 (1990)]. Briefly, this one-pot synthesis involves the dihydroxylation of β-pinene using trimethylamine *N*-oxide dihydrate/catalytic OsO_4, followed by oxidative cleavage of the diol by $NaIO_4$. This reaction proceeds in 66% overall yield.

Steven Weissman
Merck Chemical Manufacturing Division,
Rahway, N.J.

Credit for Unipol process

Recently, I was fortunate to be selected for the ACS Award for Creative Invention. My purpose in writing to you is to correct the citation (C&EN, Nov. 15, 1990, page 44), which states that my "best known work is the invention of the Unipol process." This process, a wedding of many technologies, owes its existence to a team effort. My major contribution to this process was in leading the development of the polymerization catalyst systems. It should also be noted that Unipol is not a single invention, but a body of technology with many inventions whose state of the art is continuously being advanced by us.

In closing, I would like to recognize the important contributions of my colleagues and our customers, which have made the Unipol process a commercial success.

F. J. Karol
Polyolefins Division
Union Carbide Corp.

Chemical sensitivity

This is in regard to the letter by Joseph Irgon on chemical sensitivity (C&EN, Dec. 3, 1990, page 5). During World War II, while taking a course sponsored by the U.S. Army, I, too, was subject to mustard gas exposure, albeit slightly.

The class was designed for those chemists who wished to volunteer for civil defense hazardous chemicals teaching. The course was taught at Purdue University and the graduates were then certified by the Army Civil Defense Corps as "instructors of chemical weapons." We taught block wardens, nurses, doctors, and other notable civilians on how to cope with a poison gas attack.

The first day of the class, all of us were ordered to roll up our sleeves, whereupon one drop of mustard gas was applied to each forearm. The effects were then followed during the course period on each person.

It was surprising to see the extreme differences in chemical sensitivity by different persons. Some received terrible blisters, while others (including myself) had little or no discomfort except a slight blister.

Fred C. Trager
Barberton, Ohio

Divine right of chemists

Attila E. Pavlath's letter (C&EN, Nov. 26, 1990, page 4) in response to Paul Gassman's commentary bothered me greatly. He states: "I have never met anyone in our profession who would have claimed any divine right; they only asked for human decency and fairness." This clever recasting of Gassman's complaint misses the point: Neither divine right, fairness, nor human decency are in any way guaranteed us in this world.

Based on these hypothetical (yet nondivine?) rights, Pavlath complains about the "what have you done for me today?" attitude of employers and sneers at "nonacademic managers." Are nonacademics somehow unworthy of these same elusive rights? I believe rather that these annoying nonacademicians have come to grips with a reality that does not provide a causative link between education and pay level.

I do not want or expect ACS to "stand up for the practitioners of chemistry." To whom would they stand up and on whose behalf? What would then differentiate ACS from a union? I expect ACS to act as an enabling resource to enhance

PRODUCT REPORT

Du Pont photo

Sales of Detergents Growing Despite Recession

Bruce F. Greek, C&EN Houston

In spite of gloomy economic forecasts, soap and detergent producers are expecting to see increasing dollar volume, if not physical volume, as new formulations providing better convenience for consumers improve the value-added component of their products.

Spurred by the rising prices of materials, normal population growth, and the per capita spending for cleaning products that is holding about constant despite the current recession, soap and detergent sales likely will rise more than 3% in 1991. Physical volume may be down, however, because a shift toward concentrated detergents for use in home laundry is thriving. If price margins are maintained, however, 1991 could be a far better year for the soap and detergent industry than current signs would indicate.

Nevertheless, this year could prove difficult on a volume basis for producers of soap, detergents, cleaners, and personal care products if growth slows as it has in past recessions. Most industry sources, however, expect new formulations, more innovation, and further expansion of research for future development to continue. It is ongoing efforts in those areas that support the many forecasts for increasing sales, even in a year that might have two down quarters for gross national product.

Companies of this global industry will continue to position themselves to use the innovations stemming from worldwide laboratories and engineering offices. Marketing research shows that changing consumer preferences in finished formulated soaps, detergents, and personal care products in this industry where sales in 1991 may exceed $13 billion offer a reliable trend for the future. Companies that meet current demand changes are having commercial success selling their concentrated powdered detergents, combinations in which a bleaching agent is incorporated into the formulated detergent, and in supplying the various ingredients used in desirable finished products.

The soap and detergent industry moves into this decade modifying its myriad products to adapt to environmental concerns that are gathering momentum each year. The concentrates—superconcentrates, or compacts, or ultras—provide a good example of innovation in the area of environmental concerns. The concentrates are designed to provide equally effective clothes cleaning results, while reducing the amount of packaging required, the load on municipal water systems, store shelf space requirements, and shipping and handling costs.

Current focus in the detergent industry is on development of concentrated powders. But changes also are occurring in liquid detergent products. They, too, are being formulated in higher concentrations, although recent modifications in liquids are not so extensive as in powders. Other laundry aids, especially fabric softeners, are coming to market in more concentrated form, including dilutable-by-the-consumer forms, with the objective of further reducing the number of packages to be disposed of or recycled. Many industry observers expect few other changes resulting from the growing awareness of environmental preservation needs except for the reduction in diluents for products.

It is the pressure for ever better performance at lower cost that is spurring suppliers in the industry to improve the surfactants they offer to formulators. Quality improvement programs are viewed by most suppliers as necessary to retaining cus-

A primer for soaps and detergents

Except for a few, soaps and detergents are physical mixtures of various compounds derived either from natural products or from petroleum and coal tar. The compounds are classed as surfactants, builders, bleaches, and additives.

Each compound goes into a formulated detergent to do a specific job:

- Surfactants hold dirt components in a solvent, usually water, for subsequent removal.
- Builders tie up calcium and magnesium ions to improve surfactant activity.
- Bleaches oxidize other compounds that reduce light reflectivity.
- Additives brighten colors, remove stains, reduce soil redeposition, reduce corrosion of laundry equipment, provide a desirable odor, prevent caking, and speed the mixing and other manufacturing processes.

Production: Total volume of materials produced for soaps and detergents is unknown because formulations generally are proprietary. Active ingredients, diluents, and fillers total more than 10 billion lb.

Producers: About 200 companies actively supply materials and finished soaps and detergents. Chemical companies supply the big majority of surfactants, builders, and other components. Formulators of finished products also may make chemical derivatives for captive use.

Sales: Industry shipments in 1990 are estimated at $12.8 billion, up 5.9% from 1989.

Manufacture: Diversity of products results from use of the many types of chemical reactions in the several processing steps between basic materials and finished goods. Raw materials include basic petrochemicals, natural oils, phosphorus, chlorine, hydrogen peroxide, and beneficiated ores containing carbonates and silicates.

Prices: Pricing of finished products sold to consumer and industrial markets varies widely. Basic and necessary ingredients, surfactants, averaged 55 cents per lb for 3.8 billion lb sold in 1989, the latest year for which data are available.

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tomers. Improved surfactants from these programs allow the concentrates to perform better even when used in smaller quantities.

The higher cost of improved cleaning, more concentrated formulations, and processing changes geared to meet environmental requirements appears to be acceptable to consumers. The value of shipments by the soap and detergent industry in 1990 is estimated by the Department of Commerce to be up from $12.1 billion in 1989 to $12.8 billion, an increase of 5.9%. Shipment value of surfactants alone has increased almost as much, up 5.8% to $3.9 billion.

Last year trade grew faster than total shipments but the basis was much smaller. Soap and detergent exports rose 8.9%, to $295 million, while imports rose 12%, to $165 million, according to Commerce figures.

The U.S. market for heavy-duty laundry detergents was about $3.7 billion in 1990, according to Leo R. McIntyre, an industry specialist in Commerce's office of chemicals. Of the total, 63% was sold as household detergents. Sales of heavy-duty liquid laundry detergents, after doubling in volume during the past five years, now account for more than 40% of the U.S. market. Growth has slowed to about 3% annually, McIntyre says. That is about the same as growth in powdered detergents. Liquid detergents take more than half of sales in geographical areas where phosphate materials are banned as builders in detergent formulations. However, in areas where phosphates are not limited, liquid formulations take only 30% of the market.

Bar soap shipments have grown more rapidly since 1987 than in the earlier 1980s. In 1990, shipments were 980 million lb, with a value of $1.5 billion, McIntyre estimates. Annual growth since 1987 averages 4.9%. Liquid toilet soaps account for about 10% of the market and have a volume of 32.5 million gal, valued at $143 million.

The value of product shipments of soap and detergents is forecast by McIntyre to grow 2 to 3% annually through 1995. The heavy-duty liquid detergent formulations will hold market share of about 40%, he says. However, profit margins on liquid detergents will be lower than on powdered detergents because liquids cost more to make. They require more surfactant, as much as 40% of the total in some formulations compared with about 10% in conventional powdered detergents. In the case of phosphate-free formulated liquids, more costly substitutes for the phosphate builders are used to obtain water-softening properties. McIntyre adds that, barring discovery of a builder as cost-effective as phosphates, the phosphate-free detergents are unlikely to gain a major share of the U.S. market before 1995.

Outlook is for a 2% annual increase in demand for chemicals formulated into detergents by 1995, with volume reaching about 5.5 billion lb, McIntyre says. The fastest growing demand for chemicals will be in the specialty area for products that can substitute for phosphates by adding water softening and other properties to detergents.

The only detergent chemicals whose demand is declining are the phosphates, sodium tripolyphosphate (STPP) and tetrasodium pyrophosphate (TSPP). McIntyre estimates use of STPP will decline 3% annually over the next few years, because detergents containing phosphates are banned in more than 25% of the U.S. Debate rumbles on concerning the amount of eutrophication that can be traced to phosphates in detergents, despite some evidence that 80% of the problem stems from human wastes and commercial fertilizers. Last year, about one third of detergents sold were free of phosphates. Home laundry detergents accounted for about 17% of phosphate consumption. The remainder goes mainly into various cleaners.

Although they are more costly and less effective, zeolites substituted for phosphates have become more and more popular among formulators during the past three years.

Other popular replacements in the powdered detergent market are sodium silicate and calcium carbonate. In addition to their other purposes in detergent formulations, enzymes also are being used as builders. Last year, $100 million worth of enzymes showed up in detergent formulations, a sixth of the enzyme market, by value, and the largest single use, McIntyre says. Speculation is that, as almost all enzymes will be made by biotechnology by 1995, an enzymatic method of bleaching may be developed, further increasing use of enzymes in detergents.

Builders, as a class of detergent chemicals, will grow modestly during this decade, according to a report on the outlook for detergent chemicals from a project directed by William P. Weizer of Freedonia Group in Cleveland. Demand for builders will grow 1.5% annually on the average, from less than 2.9 billion lb in 1989 to about 3.1 billion lb in 1994, and to 3.3 billion lb by 2000. The slower growth for builders than for all detergent chemicals results from a shift toward more use of surfactants at the expense of builders, particularly for detergents that are made to be sold in areas where phosphate builders are banned.

Growth in use of other builders such as sodium carbonate—soda ash—(2.0%), zeolites (8.8%), and sodium citrate (2.4%) will offset an average 1.2% annual decline in use of STPP in household detergents. Consumption of zeolites and sodium citrate, used in smaller volumes than sodium carbonate, in detergents in 1989 was some 1.1 billion lb. Use of sodium carbonate in all types of cleaning compounds was more than 1.6 billion lb, or between 11 and 12% of total U.S. use.

In detergents, soda ash functions as an agglomerating aid, a surfactant carrier, and a source of alkalinity, in addition to its builder activity. The shift toward concentrates or compacts also requires increases in density of the formulated detergents. As an example of supplier innovation to improve detergents, FMC now makes soda ash by the sesquicarbonate process as well as by the monohydrate process, says Jeffrey J. Prickel, soda ash product manager. As a result, FMC has the flexibility in special density intermediate grades to meet specific formulating needs of detergent makers.

The other nonphosphate builders are consumed in detergents in much smaller volumes. Detergent use of zeolites, for example, was 203 million lb in 1989, according to the Freedonia study. Growth is forecast to average 8.8% annually, with volume reaching 310 million lb in 1994 and 410 million lb in 2000, because of their substitution for STPP in powdered detergents. Because it is preferred for liquid formulations, use of sodium citrate will grow 2.4% annually, from 71 million lb in 1989 to 80 million lb in 1994.

Phosphate builders in cleaning products remain the best cost/performance value, various industry sources point out. Phosphates are a part of any formulation that is used as a standard of detergency, says Lewis G. Furman, marketing director of FMC's phosphorus chemicals division. The phosphates are used in concentrates for a variety of reasons, not the least of which is the long experience that formulators have with them. This is why the compacts initially have come out as phosphate-built detergents, adds Dennis E. Knudson, FMC's product manager for detergent phosphates. This development may lead to increased use of phosphates.

Technician checks cleaning efficiency of dishwasher detergents at BASF's labs in Wyandotte, Mich.

In markets for detergents other than home laundries, phosphate builders have made some notable gains. Use of both home automatic dishwashing detergents and institutional dishwashing detergents has grown and has increased demand for phosphates modestly, says Michael J. Berezo, business manager for detergent intermediates at Monsanto. A shift in sales toward the concentrated powders also might help, but concentrates without phosphates currently are under development.

The strengthening demand for phosphates has brought supply and demand for phosphorus chemicals about in balance and has permitted a price increase for STPP of more than 8%, Berezo says. Current prices are 32.5 cents per lb, up from 30 cents, the level reached after a round of large price cuts in 1989.

Phosphates consumption in cleaners in 1990 declined about 5% from 1 billion lb in 1989, estimates FMC's Knudson. However, production didn't decline as much, because of the substantial gain in exports. In fact, the net of exports over imports has gained 180 million lb over the past five years. The export growth was especially large in 1989 resulting from declines in the value of the dollar. Global production and consumption of STPP now amounts to about 2.5 million metric tons annually, according to FMC.

Bans on use of phosphate builders in detergents continue to grow, however. Two states will be added to the list of total bans, according to the Soap & Detergent Association (SDA). At the beginning of January, the ban in Georgia was scheduled to go into force. On March 1, Pennsylvania will institute a ban. Opposition by SDA to restrictions or bans on use of phosphates remains based on sound scientific data that find no

Surfactants consist of four types

The surface activity, key to effectiveness of a surfactant, depends on the chemical makeup of the molecule. The large number of compounds that exhibit surface activity are classified by the charge on the surface-active moiety, generally the larger part of the molecule.

Anionics. These surfactants have a negative charge on the surface-active moiety. They account for about two thirds of total U.S. surfactant output. Most are organic acid salts of sodium and potassium; a much smaller number are salts of calcium, ammonia, or an organic amine. Nearly all soaps are anionics. Major examples:

- Carboxylates account for about a quarter of U.S. production of anionic surfactants. Most are salts of acids derived from natural products such as coconut or palm kernal oils and tallow.
- Sulfonates are more than half of anionic surfactant production. The major categories are dodecylbenzene sulfonate and lignin sulfonates.
- Sulfuric acid esters and salts are most of the remaining anionics. Chemically, most are salts of reactions of sulfuric acid with long-chain alcohols, some of which are ethoxylated.

Cationics. These surfactants have a positive charge on the surface-active moiety, usually on an amino or quaternary nitrogen. They are expensive surfactants because of high cost of reactants and processing. As such, production is 5 to 10% of the total. Important chemical groups are:

- Amine oxides and other oxygen-containing amines, many based on natural or synthetic organic acids.
- Monoamines with long chains derived from natural oils, but not oxidized.
- Quaternary ammonium salts based on tallow or alkylbenzenes.

Nonionics. This diverse group of surfactants accounts for less than a quarter of U.S. production. Nonionics are solubilized by chains of ethylene oxide groups. They often may be used with other surfactants in formulations for very specific uses. Two major groups of nonionics are:

- Esters of carboxylic acids from natural and synthetic sources and mono- and multiglycols with long chains.
- Ethers made by ethoxylating linear alcohols and alkylated phenols.

Amphoterics. These surfactants represent a tiny fraction of total production, or about 0.6% of the 6.8 billion lb of surfactants produced in 1989. They are considered specialty surfactants and often are proprietary products offered for limited markets. Examples include:

- Alkylbetaines made from fatty acids and alkyldimethylamines.
- Imidazonlinium derivatives from reaction of imidazolines and sodium chloroacetate.

proven water quality advantages to result from lower phosphate detergent loadings, says Theodore E. Brenner, SDA president. Brenner says that where presence of heavy metals in sewage is an issue, SDA will emphasize that new research has documented that the contributions of cleaning products to the overall heavy metal content are insignificant.

Increased use in both liquid detergents and in detergents without phosphate builders will result in a growth rate of 2.3% annually for surfactants formulated in household laundry and dishwashing detergents and in industrial and institutional cleaners, according to the study by Freedonia. Consumption will reach 2 billion lb in 1994, up from less than 1.8 billion lb in 1989. If nonphosphate builders are improved, however, the growth rate may decline, as smaller amounts of surfactant are needed to get the desired cleaning performance.

It is no surprise that, because of their large volume, growth in use of anionic surfactants in these detergent markets will be lower, at 1.6% annually, than will be the 3.2% rate for the smaller-volume nonionics. The growth rate for amphoteric surfactants will be even higher at 5.5% annually, but from a tiny base of just 13 million lb in 1989. Nonionics use is expected to grow because demand for cleaning products is shifting toward liquids. Nonionics are preferred in liquids because of the ease with which they blend into liquid formulations, their somewhat better resistance to effects of calcium and magnesium ions in wash water, and their better performance in cleaning clothes made with synthetic fibers.

Output of all types of surfactants declined in 1989 about 7%, from 7.3 billion lb in 1988 to 6.8 billion lb, according to a just-issued report of the U.S. International Trade Commission (USITC) on production of synthetic organic chemicals. Output in 1990 was expected to rise about 4%, to 7.2 billion lb. An additional small growth in production of 2% is forecast for this year, which would bring the total again to 7.3 billion lb, the record for production set in 1988.

As in the past, anionic surfactants have dominated the U.S. output, accounting for almost 66% of the total. Nonionics account for about 24% of production, with most of the remainder cationic. More than half of the anionic surfactants are consumed captively, largely in the manufacture of household laundry detergents and other consumer detergent products. These surfactants, commensurate with their large volume, have, at 32 cents per lb, the lowest average unit value for 1989 merchant sales. This value is below the average of 55 cents per lb for all surfactants sold in 1989, according to USITC.

Excluding soap, global consumption of surfactants in 1990 was about 16.3 billion lb, valued at $3.65 billion, according to a new study by Colin A. Houston & Associates of Mamaroneck, N.Y. Consumption in the U.S. was about 30% of global consumption at 4.9 billion lb. Industrial uses of surfactants in the U.S. took more than 45% of the total. In the rest of the world, industrial uses accounted for 25% of consumption. The remainder of uses include household detergents, industrial and institutional cleaners, and personal care products. By the year 2000, the consulting firm predicts that global consumption of surfactants will reach 22 billion lb, and U.S. consumption will be 6.6 billion lb.

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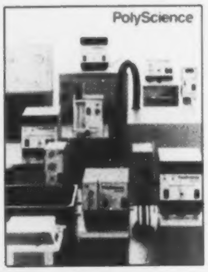

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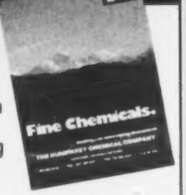

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PRODUCT PROSPECTUS

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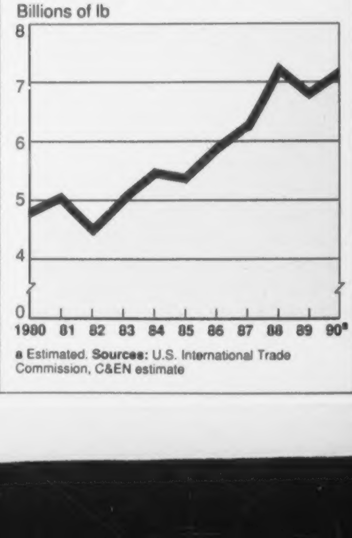
Product Report

Use of surfactants in household and personal care products in the U.S. will grow at an average of 1.3% annually between 1988 and 2000, says Marilyn L. Bradshaw, business manager at Colin A. Houston & Associates. Some new surfactants will come on the market in small volumes, but with high growth rates—such compounds as alkyl polyglucosides, methyl ester sulfonates, and paraffin sulfates. The traditional major-volume surfactants, such as linear alkylbenzene sulfonate (LAS), have stable demand. U.S. producers face increasing competition from production outside the U.S. (despite a 17.5% duty on imports), because of growing capacity around the world, according to Bradshaw.

Despite competition from other surfactants, LAS demand will grow in 1991, agrees Richard E. Lundgren, Monsanto's business manager for surfactants. This is the workhorse of the current large-volume surfactants and it will continue to hold its position because detergent and cleaner manufacturers have vast experience with formulations containing LAS and its proven safety in many use areas. The effect of changes in formulations on use of LAS will be minor this year, he concludes.

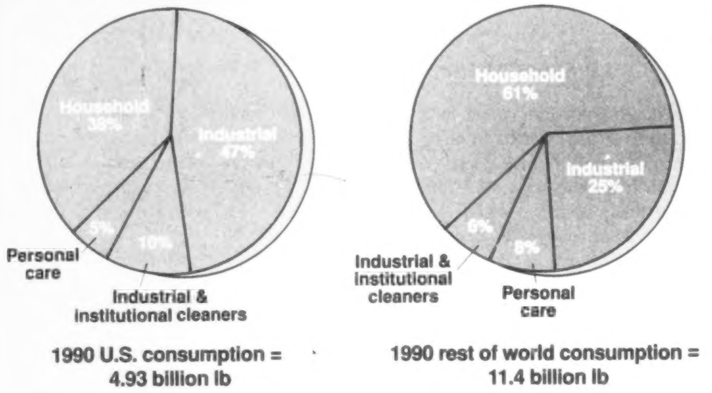
Longer term, however, greater use of enzymes and other additives likely will increase the use of mixtures of surfactants or could diminish the concentration of total surfactant in a formulation. Mixtures of surfactants in detergents offer two advantages

Organic surfactants output up but below 1988 peak



a Estimated. **Sources:** U.S. International Trade Commission, C&EN estimate

U.S. surfactant use differs from rest of world



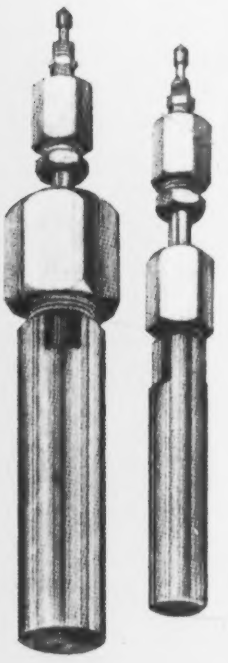
Note: Excludes soap. **Source:** Colin A. Houston & Associates

to formulators. In most cases, mixtures are easy to change to meet changes in consumer performance demands. Mixtures also allow formulators to balance or to diversify costs of the surfactants they use.

Prices of raw materials for linear alkylbenzene (LAB) have become volatile as a result of Iraq's invasion of Kuwait. When benzene prices rose to $2.00 per gal and kerosene prices more than doubled, LAB prices jumped 10 cents per lb in October, says W. Jan B. Vogel, a vice president of Vista Chemical. At the beginning of January, Vista added another 18.5 cents per lb to prices, but put a temporary voluntary allowance of 20.5 cents per lb in place for an effective decrease in price of 2 cents per lb.

In a similar fashion, prices were increased for surfactant materials based on ethylene, the U.S. prices of which increased from 22 to 30 cents per lb. In Europe, ethylene prices rose even more, going from about 25 cents per lb to 40 cents per lb. Long-chain alcohol and ethoxylate prices also increased in October and again in January, but the January increases were offset by allowances on most products.

Natural oils (also major feedstock for surfactants) recently have become more costly, says Vogel. The price increases reflect the energy component of the cost of producing and marketing the natural oils, often produced in tropical areas distant from consuming points. Prices of both coconut and palm oils increased in October from about 14 cents per lb to more than 17 cents per lb, putting pressure on prices of



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Nearly all industries use surfactants

Surfactants not formulated into detergents have applications in other major industries that produce goods. A study by Colin A. Houston & Associates indicates that industrial uses require nearly half of U.S. consumption of surfactants. But, because details of these uses are so fragmented, the volume consumed by each is uncertain.

These industries include:

- Food. Surfactants are used both as cleaners and emulsifers in food processing. The surface-active properties are used either to generate or inhibit foams.
- Pharmaceutical. Serve as emulsifiers, dispersants, and synergists for active ingredients.
- Agriculture. Used as emulsifiers (wetting agents) must not react with active materials. They must be biodegradable and have low phytoxicology. Some are used to prevent caking of fertilizers during mixing and to improve uniformity of distribution.
- Textile. Formulated more often into detergents than in other industrial uses, aid cleaning of natural fibers, reduce friction in spinning and weaving, improve application of finishes, aid dyeing, and minimize static charge.
- Chemical. Aid reactivity by their emulsification property, such as in polymerizations or hydrolyses.
- Plastics. Widely used in fabrication of plastic products such as foams, molded items, extrusions, and microcapsules.
- Paint. Aid these products, that are basically dispersions, by speeding the milling of dyes and mixing of ingredients, by maintaining stability, and by aiding the leveling of powder coatings.
- Pulp and paper. Used to help remove the cellulosic pulp from other components of wood, to reduce foam during papermaking, and to aid deinking and removing additives from recycled paper.
- Mining and ore processing. Aid dust-binding agents and act as frothing agents that hydrophobize the valuable minerals.
- Petroleum production. Used in drilling fluids to disperse and carry cuttings and are used to improve production by breaking water-oil emulsions and to aid water or other flooding of oil-bearing formations.
- Other industries using significant quantities of surfactants include tanning, fur processing, photography, metal processing, electroplating, adhesives, construction, and firefighting.

alcohols and derivatives made from these oils.

The change in pricing for basic raw materials worldwide is an integral part of the overall, mushrooming changes in global operations that companies in the detergent industry face. Other than pricing concerns and new product introduction, new markets are developing as older markets expand. For example, in 1990, Vista recognized strong growth in demand for LAB coming from its increased consumption for detergents and detergent intermediates in Eastern Europe, explains Vogel. Many industry sources anticipate further expansion of this market and others in developing countries during this decade.

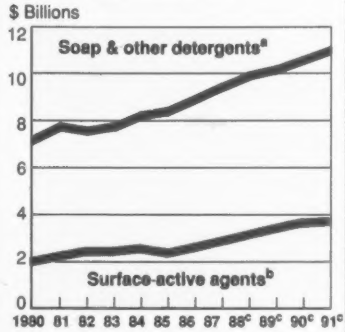
Multinational companies with access to the existing research and marketing organizations at home and abroad should be well positioned to handle the largely uncertain future of the evolving global market, says Kenneth R. Schoene, director of performance chemicals at BASF. His company has adopted "world industry-segment teams" aimed at harnessing its global resources to develop products that can meet the increasingly complex needs of detergent manufacturers. One result of BASF's product and applications research will be to introduce, during 1991, both multifunctional and soil-specific polymers and surfactants for these evolving needs, Schoene adds. Such focused activity by industry suppliers is expected to produce notable gains in raw materials that meet environmental and performance concerns.

Detergent formulators and suppliers of materials are bringing almost constant change to demand for different components, as they improve performance and lower costs while meeting new and anticipated environmental regulations. Surfactants, for example, are constantly under development, especially those that are mixtures of several similar compounds. The change from branched chain alkylbenzenes to linear alkylbenzenes in the early 1960s, to speed biodegradation of the surfactant, proved that both small and major changes in composition of molecules for performance reasons will be accepted, paid for, and spur the search for still better performance.

Extensive changes in average composition of big-volume products such as household laundry detergents are rare; changes are more evolutionary. For example, LAS continues to hold its share of the surfactant content in laundry detergents while improvements are being made in the quality of competing surfactants, such as those based on detergent or long-chain alcohols. But the position of LAS depends heavily on comparison of its cost relative to the cost of competing surfactants—the long-chain alcohol derivatives such as the ethoxylates, sulfates, and ether sulfates. Time is needed to affect compositions, but the relative costs of basic petrochemicals, such as benzene and ethylene, and of natural fats and oils, eventually will influence surfactant composition in household and other detergents.

Manufacturing cost and performance, in conjunction with other components of a detergent, partially offset consideration of the raw material costs in making a choice of surfactants. One favorable manufacturing cost factor for LAS is its ease of spray drying, a step in making powdered detergents. If a phosphate builder can be included in the formulation, then LAS likely will be used because the builder covers its greater sensitivity to water hardness than either alcohol ethoxylates or alcohol ether sulfates. However, in liquid heavy-duty detergents made for clothes washing, LAS content is reduced by replacing it in part with alcohol ethoxylates—no phosphate builders are used in liquids because they can cause a performance problem. In combination, LAS and alcohol ethoxylates appear to have a synergistic effect that permits use of

Value of cleaning products shipments will slow



a Standard Industrial Code 2841. b Standard Industrial Code 2843. c Estimated. Sources: Department of Commerce, C&EN estimates

a smaller amount of surfactant than might otherwise be needed in heavy-duty liquids.

Most light-duty liquid detergents, such as those used for hand dishwashing, have LAS as the major surfactant. Usually, alcohol ether sulfates also are used to give better grease removal and to make the product less harsh to the skin. Although liquid automatic dishwashing detergents are growing rapidly from a small base, most continue to be powders. Therefore, the light-duty liquid detergent use of LAS has remained level or has declined during the past few years. Additional, but not strong, competition comes from alcohol sulfates.

The alcohol derivatives used as surfactants go into many other products, especially personal care items such as shampoos. The alcohols are obtained either from natural products or are made synthetically from petroleum hydrocarbons. Cost of the basic raw materials influences whether natural or synthetic alcohols are used, subject to performance considerations. Sizable quantities of these derivatives are either formulated into various industrial and institutional cleaners or are used largely unformulated in industrial processes.

Many other surfactants are formulated into soaps and detergents. Most are expected to increase in demand during the nineties at long-term rates above average, because their volumes are small when compared with volumes of LAS or major alcohol derivatives. These smaller volume surfactants include the anionics, α-olefin sulfonates, and alkyl glyceryl ether sulfonates, all of which are used mostly in personal care products. Others are the nonionics, which are various ethoxylated alkyl phenols used in limited amounts in laundry detergents and household cleaners (the bulk goes into industrial cleaners), the fatty alkanolamides used in light-duty dishwashing detergents, in various personal care products, and in industrial and institutional cleaners, and the fatty amine oxides, going mostly to light-duty dishwashing detergents.

Less shifting between components of formulated detergents, especially surfactants, is expected because of efforts by suppliers to develop quality and performance standards. Suppliers are moving toward specified systems and guaranteed performance, says William R. Kristoff, Rhône-Poulenc's marketing director for surfactants and specialty chemicals. Suppliers are offering more service each year, especially in quality control. Such trends tend to reduce a customer's flexibility in changing raw materials, and cause potential suppliers more difficulty in entering a market.

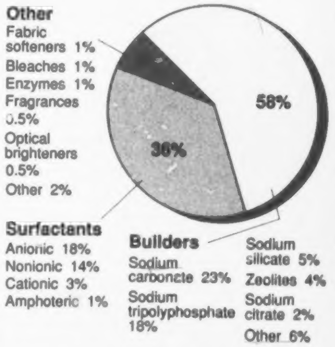
In addition to surfactants and builders used in detergents for various reasons, numerous other components are important. These include bleaching agents, fabric softeners, enzymes, optical brighteners, antiredeposition agents, fragrances, and fillers or diluents. As a group, detergent materials used in household detergents and in industrial and institutional cleaners (other than builders and surfactants) amounted to about 5% of total chemical consumption in 1989, according to the study by Freedonia.

Some of these small-volume products will have high growth during the early 1990s. For example, use of enzymes and bleaches will grow more than 10% annually because of the popularity of multifunctional detergents. Consumption of fabric softeners is forecast to grow about 5% annually, again aided by the popularity of multifunctional detergents. As a group, the other smaller volume detergent additives will grow more slowly. In the group, some specialty products, such as water-soluble polymers, could grow faster because of their multifunctionality as both builders and antiredeposition agents.

Because of consumer preference for detergents that handle stains and odors better, much development work continues to improve bleaching. Enzymes have found an important niche in formulated detergents that meet these newer consumer laundry requirements, but nearly all enzymes suitable for handling stains and other soils are deactivated by chlorine bleaches—the various hypochlorites. As substitutes for chlorine bleaches in detergents, oxygen bleaches have been around for a long time and became commercially significant in home laundry during the past decade. They will continue to grow, albeit slowly.

By far, most oxygen bleaches used in detergents, or alone, are sodium perborates. In the U.S. a shift toward lower temperatures for washing clothes has hurt use of perborates bleaches, because their efficiency declines significantly with temperature. To improve the efficiency of perborates in cool or even cold water washing, both the suppliers of perborates and other companies have worked on bleach activators. So far, success has been limited, from a cost and performance view-

Many chemicals find diverse uses in detergents



Total 1989 consumption = 4.89 billion lb

Source: Freedonia Group

point. Most bleach activators are acylating agents that react in a nucleophilic substitution with hydrogen peroxide anions in the washing liquor. These activators—complex organic chemicals—work stoichiometrically; therefore they must be present in relatively large quantities at costs too great for full activation. If activators are used in limited quantities, then only partial activation is achieved, but it often is sufficient to meet performance requirements at an acceptable cost.

The shift toward concentrated detergents for all kinds of cleaning allows strong growth for active oxygen bleaches in formulations designed to give high performance, says Frank E. Caropreso, FMC's detergent industry manager for peroxygens. Sodium perborate is being incorporated more into automatic dishwashing detergents, as formulators attempt to eliminate chlorine from these products. This bleach, as well as other peroxygens, are being considered for formulations aimed at the various industrial and institutional cleaner markets, he says.

R&D appears to be widespread on ways to activate and stabilize peroxygens in home laundry and automatic dishwashing formulations and in the industrial and institutional cleaners, including liquids. At FMC, the research focuses on finding multifunctional peroxygen carriers. So far, two promising, but undisclosed, candidates have been found in the laboratory, according to Caropreso. The concern over chlorine oxidation is expected to spur work on stable peroxygen compounds for various kinds of cleaning compounds.

Both hydrogen peroxide as a liquid bleach added directly to the washing liquor, and solid active oxygen compounds put into detergents for clothes washing, are growing well. Incentive for adding hydrogen peroxide stems from efforts to improve stain removal without damage to color or fabric. Many of the liquid bleach formulations include a surfactant added to provide greater efficacy. Another development is the use of peracetic acid, with hydrogen peroxide added, to be an acetic sanitizer in hard-surface cleaners supplied to the industrial and institutional markets of food and beverage

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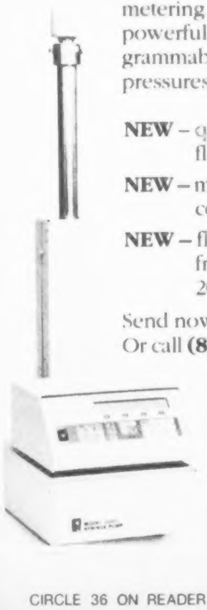

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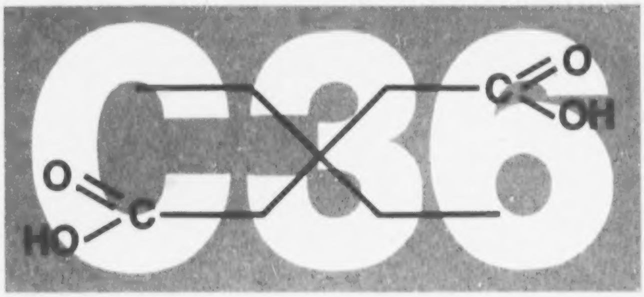

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processing. The product is also used in medical equipment sterilization.

Initially, sodium peroborate was supplied to detergent formulators as the tetrahydrate. More recently, a monohydrate form became available from foreign sources and is getting wide use. The monohydrate provides a higher oxygen content (15% versus 10% for the tetrahydrate), better stability and compatability with other ingredients (including formulations containing low phosphorus content or no phosphorus), and more rapid dissolution at lower temperatures.

This month, Du Pont will begin the first U.S. production of sodium perborate monohydrate at Memphis, Tenn., says Phillip M. Richardson, market manager for cleaning products. Du Pont will dedicate a part of the plant's tetrahydrate capacity to supply more than 30 million lb per year of monohydrates. Richardson calls this the first phase of adding monohydrate capacity to meet a growing demand in North America and in the world. He estimates that the demand for the monohydrate form in North America will increase between 60 million and 80 million lb per year in the next five years.

Numerous other additives are now required in the various kinds of detergents and cleaners offered to all segments of consumers. All are added to provide a unique function, although some act synergistically with each other. How much these materials are used in detergents and other cleaners is uncertain because, in most cases, other uses account for significant shares of production. Frequently, details of production are not reported, because only a few companies make these materials, and the volume is very small.

Enzymes, one of these small-volume substances, are incorporated increasingly into laundry detergents. Their ability to improve cleaning has been known for more than 75 years. A variety of problems, including difficulty of producing in high volume, limited wide use of enzymes until the 1980s. Most enzymes used in detergent formulations are proteases and amylases of proprietary forms.

Enzymes are added to detergent formulations, especially liquids, to

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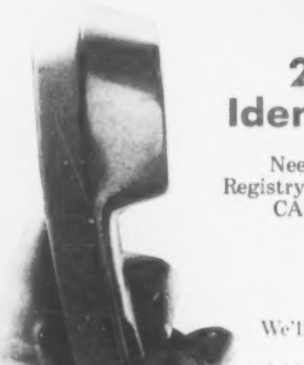

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attack proteinaceous soils, which most often appear on clothes as stains. After drying and aging, these stains strongly resist action of most low-cost and high-volume surfactants. The enzymes are then added, to attack hydrolytically a peptide or ester bond in the protein, thereby either destroying it or making the fragments easy for a surfactant to remove. Enzymes for detergents are expensive, costing over $6.00 per lb, according to Hans C. Kuenzel of Freedonia.

Fabric softeners are forecast by Freedonia to be the third fastest growing detergent additive after bleaches and enzymes. Demand for these materials will be increasing about 5% annually through 1994 to about 47 million lb. Part of the increase in use of fabric-softening additives stems from new materials that are added to multifunctional detergents. Quaternary ammonium compounds have been used as fabric softeners for some time because they are adsorbed on negatively charged textile fabric surfaces, but a wide variety of new compounds are now used in both postrinse softeners and in the multifunctionals. Other components of postrinse softeners include whitening agents, preservatives, dyes, and fragrances.

Of the miscellaneous additives in a laundry detergent formulation, one of the most important to high performance is an antiredeposition agent. To the average consumer, the best measure of poor washing performance is "greying" of the fabrics, largely a result of part of the dirt's being redeposited. For more than 50 years, sodium carboxymethyl cellulose, as an antiredeposition agent, has been known to be effective on cotton fabrics, but less so on synthetics.

Newer products added to detergents as antiredeposition agents include, for example, conventional surfactants, nonionic cellulose polymers, and polycarboxylic acids. Although the volume of water-soluble polymers used in detergents for antiredeposition agents and other functions isn't large, it is enough to spur BASF to add capacity to its plant at Spartanburg, S.C., early this year. Polymers from BASF are designed for such diverse uses as a soil

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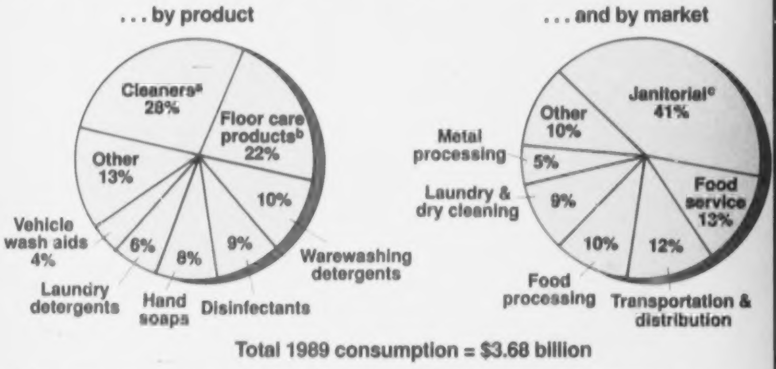
Industrial and institutional cleaning chemicals



a Alkaline, solvent, acid, and general purpose. b Waxes, polishes, spray buffs, strippers, sealers, carpet shampoos, and spotters. c Includes retail, health care, industrial and office, and contract cleaners. **Source:** Freedonia Group

shield in laundry detergents or increasing effectiveness of hard-surface cleaners, says Schoene. Further research is expected to bring out other multifunctional and soil-specific polymers this year.

Foam stabilizers as additives to detergents work both to increase and decrease the foam, depending on the application. Most light-duty liquids contain a soap to increase foam that works well with LAS surfactants. For automatic dishwashers, low foaming is needed. So, to depress foam, organic compounds that may interact with calcium ions are added.

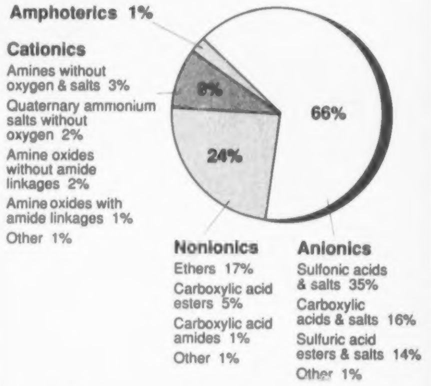
In most home clothes washing a "blueing" agent no longer is added to the rinse. Consumers now expect whiteness from the detergent. As a result, use of optical brightners continues to grow in home and industrial and institutional laundry detergents. The "blueing" agent, a dye, ultramarine blue, has worked well on cotton fabrics since its discovery in the 19th century. But with synthetic fibers, the dye works less well. As a result, optical brighteners—or fluorescent whitening agents—work as dyes to convert invisible ultraviolet light to visible light. Basic structures for these complex organic compounds include stilbene and derivatives, coumarin, quinolone, pyrazoline, and benimidazole. Acting as a dye does, these agents bind to the fiber by hydrogen bridges. Their properties that are important to good performance are an affinity for the fiber and stability and resistance to oxygen, light, and chlorine.

A wide range of other additives go into laundry detergents. Solubilizers that aid solubility of the surfactant and control viscosity, include ethanol, glycol ethers, or sodium xylene sulfonate. Corrosion inhibition is obtained if sodium silicate is added as a builder. If not used as a builder, it may be added in small quantities to inhibit corrosion. Perfumes, or fragrances, are added both to overcome the detergent's odor and to provide a favorable scent when the clothes are ready to wear. Fillers, diluents, and processing aids make up the remainder of the formulation. The shift toward concentrates of various kinds is leading to a reduction in the amount of filler and diluent in most formulations.

Household detergents and cleaners will remain the largest market for detergent chemicals, although industrial uses of surfactants could grow faster than other uses over the decade. Growth in the industrial and institutional cleaner market is second fastest, with personal care products last and smallest. Personal care products, however, are forecast to continue their slow growth unabated during the recession because this area of detergent chemicals is considered to be recession-proof.

The industrial and institutional markets take about a quarter of the detergent chemicals consumed in the U.S., excluding those that go

Anionics dominate output of surfactants



Total 1989 production = 6.79 billion lb

Source: U.S. International Trade Commission

into personal care products and industrial nondetergent markets, according to the Freedonia Group study. These markets used 10% of surfactants in 1990, or nearly 500 million lb, estimates Bradshaw at Colin A. Houston & Associates. These markets cover consuming areas such as cleaners of many kinds, floor care products, warewashing detergents, disinfectants, industrial laundry detergents, hand soaps, and vehicle washing detergents. The remaining 90% goes into household cleaners, personal care products, and industrial uses.

The industrial and institutional cleaners market with sales of more than $1 billion in 1989 will grow more slowly than other smaller segments of the total market. Considerable shifting in the kinds of cleaners used will occur through 1994, forecasts Freedonia. Use of alkaline cleaners, for example, will grow slowly because other kinds of specialty cleaners will be substituted for them. Acid cleaners also will grow more slowly because of stagnation in dairy farm use and slowness in metal-processing markets resulting from the reduction of durable goods manufacture during the recession.

The floor care markets are expected to grow because there is better acceptance of new formulations that are used with higher speed burnishing equipment and that otherwise save labor by easing application and increasing durability. More formulations prepared for specific application equipment will further help demand in the early nineties.

Detergents for these and the other smaller uses also are being reformulated for further use of automated dispensing or other application equipment. This kind of equipment helps hold down costs because it permits more accurate dosing, minimizes spills, and minimizes employee contact. Vehicle washing is one of the specialized areas in which detergents are being reformulated to meet requirements such as the very high recycling of water and minimal effluent through use of on-site treatment of waste wash waters.

Some of the industrial markets that are very specialized offer huge growth potential. Recycling paper fibers is an example. Last year, only about 50 million lb of surfactants were used in deinking and other processing of recycled paper, says Denise C. Galanci, market manager for surfactants for Union Carbide. Estimates of future demand are difficult to obtain because of the unsettled timetables for completion of the large number of new deinking plants announced throughout the U.S. Handling carbon and colorant particles, fillers, and other materials removed from the paper also offers large potential markets for flocculants, as well as other chemicals. Technical service from suppliers to recyclers will flourish as this detergent use grows.

The industrial and institutional detergent markets best exemplify the future outlook for the industry through increasingly complex formulations to meet consumer demands. As a result of demand by consumers for new products, change will continue in the soap and detergent industry. Although no innovation as significant as the introduction of concentrated detergents is expected this year, many noteworthy developments will be made. And they will continue to be made. □

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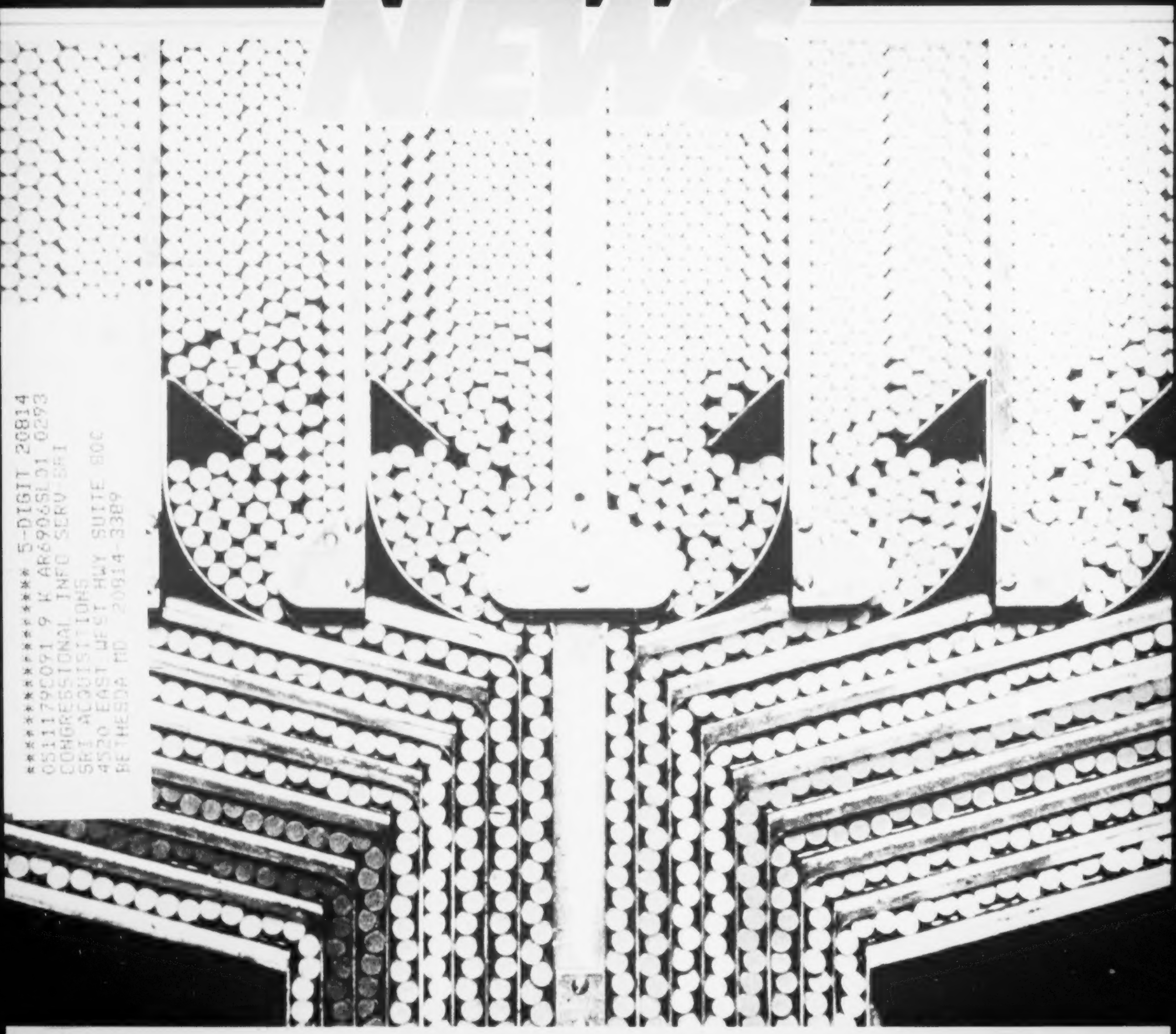

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Crayons

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Volume 69, Number 6
CENEAR 69 (6) 1–52
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CHEMICAL & ENGINEERING NEWS

FEBRUARY 11, 1991

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- **President Bush's 1992 budget proposal indicates strong support for science.** Page 4
- **IBM scientists develop technology to build "semiconductor lasers" opening up the possibility of making mass-produced, low-cost lasers.** Page 5
- **Cray Research and a consortium of major chemical and pharmaceutical firms introduce new computational chemistry software system aimed especially at industrial users.** Page 6
- **Bush Administration offers strategy for holding future U.S. greenhouse-gas emissions at or below 1987 levels.** Page 6

Business

Specialty chemicals business has lost some of its allure as companies now are finding that specialties can be hurt by such factors as economic downturn and maturing end-use markets. Page 9

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Proposed national energy strategy draws fire from a coalition of environmental, consumer, and alternative-energy organizations. Page 13

U.S. corporate research directors fault management, financial pressures, for U.S. technology lag. Page 14

High-performance computing bill that would establish national research, education network seen as crucial to U.S. competitiveness. Page 15

Science/Technology

Blue daylilies and better guitars through physical chemistry are among intellectual pursuits of FSU's Michael Kasha, honored in recent conference on photoinduced proton-transfer dynamics. Page 22

Materials & Molecular Simulation Center, one of seven such centers at Caltech's Beckman Institute, was dedicated last month. Page 25

New study strengthens previously proposed link between excitatory dicarboxylic acids and neurodegenerative disorders. Page 28

Books

Two books purportedly about the human genome project do more to elucidate genetics research in general. Page 29

Cover: Crayon sorter at Binney & Smith Crayola manufacturing facility

Cover Story

Varied formulations of pigments, paraffin, and stearic acid have brought a wide range of new colors to a basic tool of schoolchildren, the Crayola crayon. Page 19

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600 TDD (202) 872-4432
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Subscription Rates 1991. Printed editions: nonmembers U.S. 1 yr $95, 2 yr $171; outside U.S. 1 yr $131, 2 yr $243. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $12. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210.

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LETTERS

CHEMICAL SAFETY

Alkyllithium reagents

Small fires caused by alkyllithium reagents (methyllithium, butyllithium, and *tert*-butyllithium) have been experienced in many chemical laboratories. The most disliked and dangerous work with these reagents is disposing of unwanted ones.

We have found that poly- or oligo(dimethylsiloxane) (PDMS or ODMS) is a useful reagent for deactivating alkyllithiums compared with the ordinary alcohols or other deactivating reagents. The advantages are: (1) No flammable gaseous by-product such as methane is generated. Alkyllithium compounds react with siloxane polymers to form cleaved polymers with alkylsilyl groups and lithium silanolate groups. (2) The basicity of the resulting lithium silanolate is weaker than that of corresponding lithium alcoholate. (3) The quenching reaction is mild; i.e., careful addition is not necessary.

A typical procedure is like this: Alkyllithium to be disposed of is added to a tetrahydrofuran solution of PDMS (Dow Corning 200 fluid 100 centistokes or its equivalent, known as "silicone oil" for oil baths; about 50% weight by weight solution, more than 100 g as PDMS to 1 mole of alkyllithium) and mixed for several hours. The solution is neutralized (if needed) by addition of acetic acid and discarded as a common organic waste material.

This method might seem expensive, but nothing is more expensive than a fire and subsequent explosion.

Toshio Suzuki
Research and Information Center
Dow Corning Japan Ltd.

A two-tiered faculty

It seems to me that American universities have extended themselves too much. At the undergraduate level, they attempt to be all things to all people. Since many entering students are inadequately prepared for college-level studies, most universities provide remediation at the freshman level. Since many graduate programs have emphasized research and deemphasized coursework, undergraduate curricula have had to incorporate additional material at the junior and senior levels. Another onus is the need to serve as a job-training center; thus the need to provide very specialized courses utilizing specialized equipment. This was not expected of the universities of the 1940s, 1950s, and 1960s.

At the graduate level, American universities have assumed the responsibility of doing much of this country's basic scientific research. Today's science faculty members are generally less professorial and more egotistical than were their counterparts in the earlier university system. It is not unusual for a chemistry faculty member at a large research university to teach only one or two courses each year! It is also typical for a research faculty member to be preoccupied with getting grants, publishing papers, and fattening his or her résumé. Graduate students are often thought of as just pairs of hands to do the mechanics of the research; undergraduate students are practically forgotten in the research shuffle. Professional research faculty are so engrossed in their research that they have little time to educate students.

This modern concept of university purpose—at both the undergraduate and graduate levels—began evolving in the mid- to late 1970s. Some results are obvious in the areas of science and technology. Today, graduating students are seldom generalists with a broad mastery of scientific concepts. They tend to be specialists with little or no expertise outside their narrow area of interest. They fit quickly into a specialized industrial or research job, but are not necessarily prepared to grow with the job. Persons educated at American universities in the 1940s, 1950s, and 1960s needed on-the-job training as provided by their employers. They brought to the job a general education involving ideas, theories, and problem-solving. They were not knowledgeable about what sequence of buttons must be pushed to operate a specific instrument, but they understood the general principles involved in the instrument's operation. Such people were able to grow and expand as their job duties expanded. Certainly, American industry and technology operated more efficiently and competitively then than now.

I offer the following suggestion as a

Specialty Chemicals Business Losing Some Luster

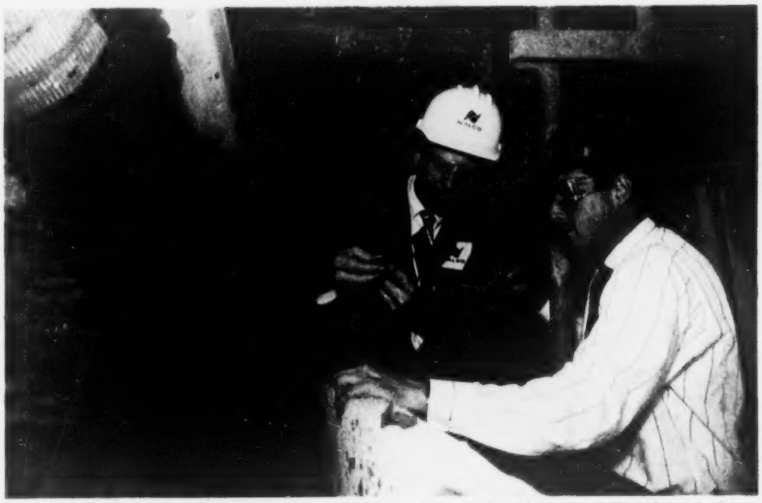
Demand growth, acquisition activity have slowed for some specialties buffeted by such factors as economic downturn, maturation of end-use markets

Susan J. Ainsworth, C&EN Houston

In the early to mid-1980s, specialty chemical businesses were too good to be true, promising continuous high performance and profits. So it was not surprising that so many companies were snatching up these specialty chemical gems at record pace and for record price tags, while others rushed to find ways to relabel a broad spectrum of chemical products as "specialty."

And indeed, specialty chemicals do have some advantages over commodity businesses that will help them weather the current recessionary storm and look to bright skies in the future. Especially well positioned will be companies in a select number of high-flying segments, such as the environmental area, with its certain, regulation-driven sales growth.

However, the industry's perceptions of specialty chemicals have come down to Earth over the past 10 years. Acquisition activity has mellowed and companies have come to realize that "specialties are subject to many of the same issues confronting those of the overall chemical industry, such as maturation of end-use industries and the characteristic pressures of the economic environment," says Larry D. Rosenberg, a director at Chem Systems, Tarrytown, N.Y., who spoke at a recent conference on "Competitive Advantage in the 1990s," sponsored by the consulting firm.



Sludge dewatering currently is fast-growing market for specialty chemicals

Looking ahead into 1991, "I don't see a rosy picture or a stellar increase in profitability" for specialty chemicals, says Karl D. Loos, managing director of Arthur D. Little's chemicals and plastics practice. Industry demand growth will be stagnant to slightly up over 1990 and profit margins will likely be compressed, he predicts. That means that the specialty chemicals business may grow only 3 to 4% per year, "just a little better than the gross national product," Loos adds. The boost that specialties got from electronic and high-tech areas in the last recession won't be there this time, he says. "Specialties will not get singled out as being recession-proof."

Fewer specialty companies are changing hands

Region	1989	1990	% change
U.S.	62	47	-24%
Western Europe	43	42	-2
Rest of world	15	15	0
TOTAL	120	104	-13%

Note: All figures for January through June periods only.
Source: CHEMTRAK, Kline & Co.

And most specialty companies don't expect to totally buck the recessionary trend. "We do not believe specialty chemicals are recession-proof," says John R. Webb, president of Exxon Chemical's performance products group. "When demand for our customers' products (often commodity in nature) falls off due to a recession, our process aid and product additive businesses are impacted—but generally not as dramatically as the commodity businesses.

"In specialties, we're basically in the problem-solving business. Lower profits in our customers' shop translate to their taking a very hard look at all their costs. In some cases, they may choose to live with their problems rather than try to solve them."

On the other hand, sometimes specialties can be something a customer may resort to getting into in a slow market environment, notes Walter F. Schlauch, group vice president for adhesives, resins, and specialty chemicals at National Starch & Chemical. If producers in an industry fall upon tough times, they may actually turn to a more specialized product—for example, something in the adhesive or paper businesses—if it will help them increase efficiency, he says. "But while a downturn in the economy can sometimes present an opportunity of this sort, I don't think that the negative impacts of a recession can be ignored by any means."

Certainly, the Middle East war has contributed to higher oil prices, which has led to higher raw material prices for specialty chemical producers. "Now oil prices are back down some, but oil-based raw materials prices have not come down as quickly," says Mary Kay Kaufmann, marketing manager for industrial water treatment chemicals at Nalco Chemical. "I don't know where raw material prices will level off," she adds.

Exxon Chemical's Webb says: "How the Middle East war will impact our businesses varies all over our product slate. High crude costs could hurt [profit] margins and demand in our paper chemical business, for example, but could benefit our oil field chemicals business since the high crude prices, if sustained, would encourage added production and mean more opportunities for us."

Nalco's Kaufmann adds: "There's a direct tie from how many wells are pumping to how much business we do" in the oil field chemicals area domestically. Last spring chemical consultants Kline & Co. estimated that the $680 million market for low-volume, high-priced oil field chemicals products would grow 6% per year between 1989 and 1994.

"In a scenario where you have high energy prices combined with recession, other specialties that are energy-savings driven also should do well," Webb says.

"And anything associated with the environment will show above-average industry growth," including environmental remediation products or services or environmentally friendly alternatives to existing products, points out Robert Henske, director of ADL's chemicals and plastics practice. The environmentally oriented specialty chemicals segment as a whole is growing roughly 6% a year, according to some estimates. But many of these niches are experiencing double-digit growth of about 15 to 20% per year, says Kaufmann. One such segment is sludge dewatering; an increasing number of industrial plants need to dewater the sludge that results from wastewater treatment processes to reduce the waste volume that will go into a landfill.

Indeed, Nalco is one company capitalizing on the environmental trend. "I would say that right now we believe that we are recession-proof," says Kaufmann. "Now, that's assuming that the recession does not come to the point where major businesses and industries are shutting down their operations like back in the early 1980s."

Cutbacks in the environmental controls area are rarely an option for customers, even when tough economic times abound, Kaufmann points out. Simply put: "Just because a recession hits, it does not mean you can start polluting."

The tightening noose of regulation means that more companies are being forced to clean up their industrial acts. This generates more opportunity for specialty chemical companies, particularly those who take a broad, flexible approach in responding to this trend. "In addition to providing new chemicals, suppliers will need to develop new systems and new technologies, in many cases, to meet the changing needs of their customers," according to the November/December 1990 issue of Stanford Research Institute's *Chemical Industries Newsletter*.

Webb: specialties not recession-proof

For example, last year Nalco teamed up with London-based Fuel-Tech N.V. to market its NOxOUT process, a cost-effective technology used to reduce nitrogen oxides produced by the combustion of fossil fuels from stationary sources such as industrial and electric utility plants. Tougher regulations on the emission of nitrogen oxides—which are a major ingredient in acid rain and ground-level ozone—likely will create "an excellent market for the technology," says Nalco.

Other companies are busy tapping the market for "environmentally friendly" products aimed to replace less desirable existing products. "These kinds of green products, while it is unclear how long their life will be, will be strong contributors to profitability at least over the next decade," says Loos.

For example, National Starch recently developed a cornstarch-based packaging material that can be a substitute for the widely used polystyrene "peanuts." The material, tradenamed Eco-Foam, dissolves readily in water. It leaves no toxic residue behind once it is decomposed, the company claims. No chlorofluorocarbon blowing agents are needed to make Eco-Foam loose fill. It is extruded in the same equipment and in much the same manner as some breakfast cereals and snacks—using a simple steam and heat system. Packaging material producer American Excelsior, Arlington, Tex., is the exclusive licensee for manufacture and distribution of the material in the U.S.

Beyond the environmental area, several other niches have been singled out to produce strong growth over the next few years. For example, Kline expects diagnostic aids to grow from a base of $3.08 billion in 1989 by 12% per year through 1994. For that same period, it forecasts low-volume, high-priced specialty

National Starch's new packaging material can be used in existing dispensing equipment

polymers to grow from a 1989 base of \$3.05 billion by 9% per year; and electronic chemicals and specialty materials to grow from \$3.40 billion by 8% per year.

Fewer companies have been relying on acquisition as a way to move or expand into lucrative specialty businesses. For the first half of 1990, acquisition activity in specialty chemicals was 13% below the corresponding 1989 level, according to Kline. According to CHEMTRAK, Kline's acquisition tracking service, a total of 104 transactions occurred in specialty chemicals in 1990, compared with 120 during the first six months alone in 1989. The largest decrease is in the U.S. where the number of acquisitions was down 24%. Meanwhile, Europe and the rest of the world have remained fairly steady, says Kline.

A decreasing number of U.S. specialty chemical companies may be changing hands because of a number of factors. First, the collapse of the junk bond market has made it difficult for many finance-driven acquirers to find sufficient financing, Kline conjectures. Another possible deterrent: uncertainties about the overall health of the U.S. economy.

Slower growth and a murky future for specialties mean that it may take longer to pay back premiums on acquisitions, so fewer companies are attracted to the acquisition route, Henske reasons.

Says Exxon Chemical's Webb: "Simply put, in 1989 and 1990 the price tags on potential acquisitions got too high. Right now, in today's economic climate, people are tending to be much more conservative. But it also can be a good time to buy, if the fit is right. We continue to have our eyes open for the right opportunities."

More companies are moving into specialties through a slow internal "evolution" process rather than the "revolution" of just buying into specialties through acquisition, notes Henske. "It's all part of the industry's quality programs where companies are learning more about who their customers are" and how they can more specifically meet their needs, which often involves performance-oriented chemicals and services that fall under the specialties guise.

Indeed, one of the major challenges for the 1990s will be increased competition even while demand in certain business segments shrinks. The forward integration of larger companies that are nontraditional specialty firms will make it harder to discern who is a specialty company and who is competition, says Loos.

Kaufmann: environmental markets provide double-digit growth

"The best way around the competition is to develop your own strategy of segmentation or differentiation. You have to look at your entire environment and carve out your particular niche," warns Abe Fenster, a general manager at ICI Americas, who spoke at the Chem Systems conference. "But be sure you have completely analyzed the market so that you really do carve a niche" rather than "dig a hole."

Keeping ahead of the competition in the laboratory and on a global scale will be no easy task. "For specialty companies, global competition and technological obsolescence will be among management's largest challenges" in the future, says Chem System's Rosenberg.

Companies continue to expand their geographical boundaries. But over the past two years, they have developed a clearer focus of what their positions are in specific regions of the globe, notes Schlauch. For example, rather then target individual countries, a company may adopt a more regional strategy designed for Europe post-1992 or a particular trading block, he adds.

Certainly, technological obsolescence is always a threat. The restructuring and downsizing of basic industries such as automotive and electronics is certainly not good news for specialties. "Along with these changes have been new, sometimes smaller and often specialized, requirements to meet the needs of these basic industries and other new ones that are formed, notes Rosenberg. Webb echoes that the specialty chemicals business is facing "more pressure from its customers to provide more sophisticated solutions and improved distribution systems."

Henske predicts products will have much shorter life cycles, so firms will need strong technical and R&D efforts to recoup and develop new products at a faster pace to meet demand. The companies that are successful at this game will not necessarily be the ones with the biggest R&D budget, but those that best manage those monies to ensure that they will be spent productively, he adds. "That will be one of the greatest challenges of the 1990s." □

Chemical company earnings continue to slump Page 18

NEWS

Federal R&D Budget '92

President gives special emphasis to basic research, but seeks more funds for all areas Page 7

CHEMICAL & ENGINEERING
NEWS

Volume 69, Number 7
CENEAR 69 (7) 1-56
ISSN 0009-2347

FEBRUARY 18, 1991

News of the Week

- **Department of Energy issues long-awaited "reconfiguration" plan for future of its nuclear arms complex, and Office of Technology Assessment issues extremely critical report on the problems of cleaning up the past sins of the complex.** Page 4
- **FDA orders Monsanto to stop promoting genetically engineered bovine growth hormone while it is still under review.** Page 5
- **U.S. leadership in biomedical research is slipping, according to Gallup poll that surveyed academic and industrial research leaders and NIH grantees.** Page 5
- **Stanford research group develops superconducting superlattice that could provide easier route to sandwich-type tunnel junctions, among other potential applications.** Page 6

Business

Earnings of major chemical companies slumped in 1990 primarily because of higher feedstock costs, continued sag in the economy. **Page 18**

Government

Rising costs of pollution control may force EPA to change regulatory direction, leading to adoption of pollution prevention strategy. **Page 25**

Charles Benbrook, former executive director of NAS's Agriculture Board, remains upset over his discharge and the reasons behind it. **Page 27**

Science/Technology

Strategies for environmental management in the next decade and beyond were put forth by environment ministers of the 24 OECD nations meeting last month in Paris. **Page 32**

Biological mineralization—the process that forms bones, teeth, and shells—is mimicked in artificial system. **Page 33**

Hints to researchers on how to maintain electronic records for patent purposes offered in free ACS pamphlet. **Page 34**

Books

"**Making Science Our Own**" surveys writing about science in the U.S. 1910–55, and details how myths were perpetuated. **Page 35**

ACS News

Project to produce a sourcebook for aiding handicapped chemists is making strong progress. **Page 39**

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News Focus

Bush's proposed 1992 budget would give a healthy boost to basic and applied research programs with projects such as the Superconducting Super Collider and human genome research receiving hefty hikes. Page 7

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1155—16th St., N.W., Washington, D.C. 20036

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Published by
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Subscription Rates 1991. Printed editions: nonmembers U.S. 1 yr. $95, 2 yr. $171; outside U.S. 1 yr. $131, 2 yr. $243. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel. (03) 272-7211. Single copies: Current $12. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

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LETTERS

Chirality in pharmaceuticals

Seemon H. Pines' response (C&EN, Nov. 26, 1990, page 5) to Stu Borman's feature article on chirality (C&EN, July 9, 1990, page 9) clearly states that chemists are trained in the art of asymmetric synthesis and are capable of designing economically feasible routes to enantiomerically pure or enriched pharmaceuticals. To a great extent their task has been simplified by the commercial availability of chiral, enantiomerically pure building blocks.

Because of demand, industry has undertaken the challenge of developing commercial-scale processes that remove the stigma of "laboratory curiosity" from elegant asymmetric synthetic reactions. For example, the commercial availability of enantiomerically pure, chiral glycidols is not only a reflection of K. Barry Sharpless' novel epoxidation reaction, but a testament to the ability of process chemists and engineers who made multiton production possible.

With production at such a scale, the pharmaceutical industry can be assured of versatile, enantiomerically pure building blocks at reasonable costs. This will allow the growing trend toward enantiomerically pure or enriched chiral drugs to continue without the "extreme increases in production costs" forecast in Borman's article.

Harry Mazurek
Project Manager
Arco Chemical

A necessary adjective

We must of course accept Robert L. Wolke's claim to be a lifelong student of English (C&EN, Nov. 12, 1990, page 43). He should then be aware that the trouble he is trying to evade started a long time before the U.S. was born. The English word "chemical" has been used since the middle of the 16th century as an adjective with the connotation of belonging to, relating to, or having been obtained by chemistry; half a century or so later, in 1615, by extension it was used to describe people with the connotation of being versed in chemistry. Starting in the middle of the 18th century it has become used as a noun—usually in the plural—its original significance being in distinguishing those compounds made by chemists from those occurring naturally.

We (that is, we members of the American Compound Society, as I suppose we should now be called) nowadays do not make such a distinction, having more chemical knowledge, and perhaps more respect for the "unnatural." Popular opinion, once fashioned by education, now molded by "the media," has been forced to overreact to the cynical mistreatment of nature by the chemical industry over the past century and a half, but we need not compound (chemical?) this by overreacting in our turn and banning a useful shorthand noun, not to say a necessary adjective.

John R. Millar
Blagdon, England

Political environmentalism

The book review by Jim Sibbison (C&EN, Oct. 29, 1990, page 31) cannot remain unchallenged. As a charter member of the Environmental Protection Agency, I am proud of our accomplishments. At the same time, I am less than proud that many mistakes were made and numerous opportunities were lost.

When EPA was formed, all of us enthusiastically accepted the support of political advocacy groups. Most of us were dedicated to the protection of the environment, which was a declared goal of these advocacy groups. However, gradually it became clear that there were two distinct approaches for establishing environmental priorities, regulating environmental pollutants, and imposing controls. Whereas the scientific environmentalists chose to rely upon the best available scientific information, the political environmentalists relied upon political advocacy and ideology. The scientific environmentalists were essentially apolitical. Conversely, the political environmentalists wanted a scientific justification for their preconceived actions by choosing data that fitted their requirements and disregarding every other information. When confronted, they found many excuses for not relying upon best available scientific information. These excuses were expressed as lack of data, the need for prudence, and disagreement among scientists on

Letters to the Editor

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Administration's 1992 Budget Proposes a Healthy Boost for R&D

Basic research would increase 8%, grabbing 18% of total R&D budget, and funds for applied R&D would jump 13%; Superconducting Super Collider and human genome research would get big hikes

David J. Hanson, Janice R. Long, and **Pamela S. Zurer,**
C&EN Washington

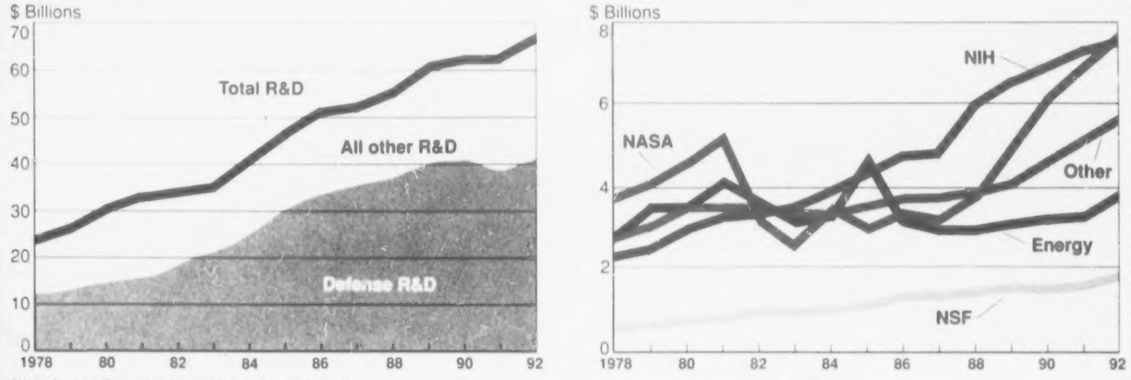
In submitting his second comprehensive federal budget proposal to Congress, President Bush repeated a major theme found in his first budget—the importance of research and development, particularly basic research, to the economic and social health of the nation. For fiscal 1992, he once again calls for increasing federal R&D spending by a much larger percentage than overall federal spending, which is up 4% to $1.44 trillion.

In the White House's fiscal 1992 budget proposal, obligations for the conduct of R&D would rise 12%, or $8 billion over current levels, to $72.1 billion. Within that total, obligations for defense R&D, conducted by both the departments of Defense and Energy, would increase 14% to $43.2 billion. Obligations for civilian R&D would be up 9% to $28.8 billion.

Obligations for basic research are slated to increase 8% to $13.3 billion, accounting for 18% of the federal R&D budget. Civilian basic research would rise 9% to $12.3 billion, and defense basic research would rise 2% to just over $1 billion. Overall obligations for applied R&D would increase 13% to $58.8 billion, with those for defense up 15% to $42.2 billion and those for civilian applied work up 10% to $16.6 billion.

Highlights of the fiscal 1992 basic research budget, as selected by the Office of Management & Budget, include increases of:

- $406 million to $2.7 billion to put the National Science Foundation back on track to doubling its budget, this time by 1994.
- $334 million to $5 billion for increasing basic biomedical research at the National Institutes of Health.
- $291 million to $534 million for the Superconducting Super Collider.
- $52 million to $125 million for an expanded agricultural research initiative.



Defense accounts for 60% of R&D spending . . .

. . . while NIH, NASA account for largest budgets in nondefense R&D

Note: Outlays **Source:** Office of Management & Budget

- $35 million to $165 million for the human genome project.

In the applied R&D area, OMB singles out the $903 million, an increase of $227 million, set aside for energy R&D; $638 million, up $149 million, earmarked for high-performance computing and communications; and a $1.3 billion advanced manufacturing and materials program, whose funding actually declines by $6 million in fiscal 1992.

An additional $3.5 billion, 15% more than is being spent this year, is earmarked for construction, repair, and modernization of R&D facilities, bringing total proposed federal support for R&D to $75.6 billion, an increase of 13% over fiscal 1991 funding levels.

In the following sections, C&EN provides a closer look at the R&D budget proposed for the various federal agencies that support R&D activities, starting with the largest R&D funding source and descending to the smallest.

Defense Department. The past two years have seen the DOD research and development budget proposal take a beating from Congress, but the Administration is once again asking for a large increase. This year, basic and applied research would receive about $3.9 billion and development and testing more than $36 billion. This is a 15% increase for DOD over last year's figures, and it contrasts with the slower rate of growth (about 12%) proposed for civilian R&D programs.

The Administration says in fiscal 1992 DOD's basic research program will place new emphasis on high-performance computing and improved materials for electronics, gas-turbine engines, and airframe components. Initial estimates indicate individual investigators will be funded at about the same levels as they are in the current fiscal year since funding for DOD's basic research programs is not increasing so fast as inflation, which the Administration estimates will be running at a rate of 3.8% in fiscal 1992.

DOD's proposed R&D budget will also support such development projects as Sematech, the semiconductor industry consortium formed to advance the manufacture of semiconductor materials, and the nation-

TOTAL FEDERAL R&D BUDGET PROPOSAL

Outlays for R&D are up 7% . . .

	Obligations			Outlays		
$ Millions[a]	1992 proposed	1991 enacted	% change	1992 proposed	1991 enacted	% change
BY AGENCY						
Defense[a]	$40,479	$35,176	15%	$38,421	$36,142	8%
Health & Human Services	9,836	9,273	6	9,235	8,704	6
NASA	8,602	7,271	18	7,767	6,974	11
Energy	6,410	6,149	4	6,273	5,810	8
NSF	2,112	1,828	16	1,897	1,675	13
Agriculture	1,261	1,224	3	1,198	1,152	4
Interior	562	584	−4	567	572	−1
Commerce	538	517	4	499	454	10
EPA	491	433	13	450	418	8
Transportation	435	407	7	411	373	10
Agency for International Development	413	385	7	445	337	32
Veterans Affairs	219	219	0	219	215	2
Other agencies	720	645	12	684	611	12
BY FUNCTION						
Applied R&D	**58,758**	**51,791**	**13**	**55,650**	**51,840**	**7**
Defense[b]	42,206	36,760	15	40,147	37,794	6
Civilian	16,552	15,031	10	15,503	14,046	10
Basic research	**13,319**	**12,320**	**8**	**12,416**	**11,597**	**7**
Civilian	12,278	11,296	9	11,364	10,623	7
Defense[b]	1,041	1,024	2	1,052	974	8
TOTAL	**$72,078**	**$64,111**	**12%**	**$68,066**	**$63,437**	**7%**

. . . as are those for basic research . . .

	Obligations			Outlays		
$ Millions	1992 proposed	1991 enacted	% change	1992 proposed	1991 enacted	% change
Health & Human Services	$ 5,477	$ 5,101	7%	$ 5,097	$ 4,786	6%
(NIH)	(4,968)	(4,634)	7	(4,622)	(4,372)	(6)
NSF	1,987	1,719	16	1,784	1,560	14
NASA	1,960	1,698	15	1,800	1,612	12
Energy	1,759	1,726	2	1,654	1,650	0
Defense[b]	1,010	992	2	1,021	942	8
Agriculture	598	563	6	553	539	3
Other agencies	529	521	2	506	507	0
TOTAL	**$13,320**	**$12,320**	**8%**	**$12,415**	**$11,596**	**7%**

. . . but outlays for R&D facilities rise 15%

	Obligations			Outlays		
$ Millions	1992 proposed	1991 enacted	% change	1992 proposed	1991 enacted	% change
Energy	$1623	$1199	35%	$1442	$1161	24%
NASA	885	857	3	850	722	18
Defense[b]	538	461	17	482	463	4
NSF	153	111	38	124	155	−20
Agriculture	128	156	−18	122	148	−18
Health & Human Services	130	186	−30	153	111	38
Other agencies	88	113	−22	93	86	8
TOTAL	**$3545**	**$3083**	**15%**	**$3266**	**$2848**	**15%**

Note: All numbers are estimates. **a** Numbers exclude R&D facilities funding. **b** Includes military-related R&D programs of the departments of Defense and Energy. **Source:** Office of Management & Budget al aerospace plane program, which is being run in conjunction with NASA.

The largest single item in the R&D proposal is funding for the Strategic Defense Initiative. Although cut back significantly last year by Congress, SDI funding is proposed at $4.6 billion for fiscal 1992, up from $2.9 billion this year. The SDI program has been refocused. Research is now aimed at protection from accidental or unauthorized ballistic missile launches.

Health & Human Services. The Administration has asked for about $10 billion in fiscal 1992 for research and training at HHS. The bulk of those funds are commanded by the National Institutes of Health, which would receive a 6% increase over 1991 to $8.8 billion. NIH is the largest single source of support for biomedical research in U.S. universities, including almost one third of academic chemistry research funding.

NIH has long enjoyed special treatment from Congress, which regularly appropriates more money for the prestigious institution than the President requests. For example, Congress awarded NIH $8.3 billion for fiscal 1991 although Bush asked for only $7.9 billion. But the word on the NIH grapevine is to expect the pattern of Congressional largess to be broken this year, given the unprecedented stresses on the federal budget. NIH officials are figuring that what the Administration has requested is all they will get for fiscal 1992.

After being inundated by complaints from the scientific community about the shortage of grants from NIH, last year both the House and the Senate Appropriations committees instructed NIH to take a hard look at managing costs. The committees suggested NIH gradually raise the number of new grants it awards each year to 6000 while simultaneously holding down cost increases. Many scientists and research administrators welcome the proposal to increase numbers of grants, but others are afraid a target of a specific number of grants could lead NIH to fund the cheapest rather than the best grants if the budget did not grow sufficiently.

The current NIH budget request allows modest growth in the number of grants without cutting their size. Funds for research project grants awarded by NIH to outside research institutions would increase 9% to $4.9 billion in fiscal 1992. That would allow NIH to support 21,818 grants, about 600 more than in fiscal

DOD seeks return to R&D increases

$ Millions	1992[a]	1991[a]	1990[b]	% change 1991-92
Engineering development	$11,135	$ 9,050	$11,025	23%
Advanced development	11,128	10,525	10,249	6
Operational systems development	10,830	8,442	9,238	28
Management & support	2,960	2,689	2,775	10
Exploratory development	2,860	2,724	2,408	5
Research	1,010	1,125	936	−10
TOTAL	$39,923	$34,555	$36,631	16%

Note: Obligations. a Estimate. b Actual. **Source:** Department of Defense

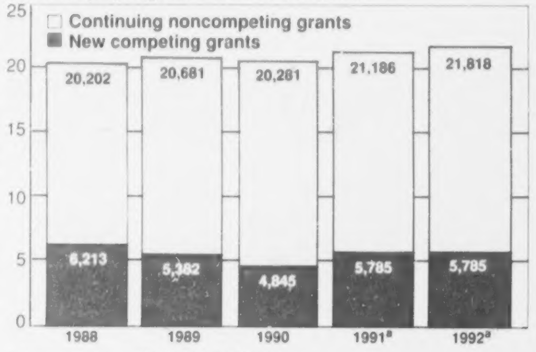
NIH's human genome R&D again scores big

$ Millions	1992[a]	1991[a]	1990[b]	% change 1991-92
National Institutes	$7980.0	$7439.0	$6893.9	7%
Cancer	1810.2	1713.8	1643.4	6
(AIDS)	(169.0	159.8	149.3	6)
Heart, Lung & Blood	1209.9	1126.9	1070.7	7
(AIDS)	(45.7	43.4	42.1	5)
Allergy & Infectious Diseases	976.7	907.3	832.2	8
(AIDS)	(459.3	433.6	394.1	6)
General Medical Sciences	833.2	760.0	710.6	10
(AIDS)	(16.5	15.6	14.6	6)
Diabetes & Digestive & Kidney Diseases	658.6	615.3	580.2	7
Neurological Disorders & Stroke	583.4	541.7	489.3	8
(AIDS)	(17.6	16.5	16.2	7)
Child Health & Human Development	520.6	479.0	442.0	9
(AIDS)	(34.7	31.0	26.7	12)
Aging	348.6	323.8	238.9	8
Eye	272.3	253.2	236.5	8
Environmental Health Sciences	254.5	241.0	228.7	6
Arthritis & Musculoskeletal & Skin Diseases	204.8	193.2	168.6	6
Dental Research	160.9	148.9	135.5	8
Deafness & Other Communication Disorders	146.3	134.9	117.3	8
National Center for Human Genome Research	110.5	87.4	59.5	26
National Center for Research Resources[c]	321.0	335.3	337.1	-4
Other	363.5	415.0	285.9	-12
TOTAL	$8774.9	$8276.7	$7576.4	6%

Note: Obligations for AIDS research are included in totals for each institute. Subtotals for AIDS are broken out where they exceed $10 million. a Estimate. b Actual. c Previously known as Division of Research Resources. **Source:** National Institutes of Health

NIH budget would allow modest growth in total grants

Research project grants awarded, thousands



a Estimated. **Source:** Health & Human Services

NASA focuses on space and Earth sciences

$ Millions	1992^a	1991^a	1990^b	% change 1991-92
Space station	$2022.5	$1894.5	$1714.9	7%
Scientific investigations in space	1932.6	1588.8	1365.1	22
Physics & astronomy	1132.3	1000.0	873.1	13
Planetary exploration	618.8	455.3	385.8	36
Life sciences	181.5	133.5	106.2	36
Space applications (Earth sciences)	976.6	929.3	641.9	5
Space transportation capability development	865.9	658.9	637.3	31
Aeronautical research & technology	587.2	511.5	449.3	15
Space research & technology	415.3	305.2	285.2	36
Commercial programs	146.8	89.9	58.3	63
Transatmospheric vehicle	73.2	92.4	59.1	-20
Academic programs	64.1	61.7	28.2	4
Safety, reliability & quality assurance	33.6	35.3	21.9	-5
Tracking & data systems	21.9	19.5	19.8	12
TOTAL	$7139.7	$6187.0	$5281.0	15%

Note: Obligations. a Estimate. b Actual. **Source:** Office of Management & Budget

1991 and an all-time high. Of those, 5785 would be new grants, the same number projected for fiscal 1991. The request allows the average cost of both continuing and new grants to increase at the rate of inflation.

"We can be very pleased given the context of the overall budget constraints," says Marvin Cassman, deputy director of NIH's National Institute of General Medical Sciences. "There is a clear emphasis being given to research project grants. There is an expansion of the number of grants overall, without a squeeze on the size of the grants."

NIGMS, which is the source of most NIH funds that go to chemistry departments, would receive a 10% increase in fiscal 1992 to $833 million. That's a larger increase than any other NIH entity except for the high-profile Center for Human Genome Research. Bush has requested a 26% rise to $110 million for the center's project to map and sequence human chromosomes.

AIDS research, spread throughout most NIH units but concentrated in the Institute for Allergy & Infectious Disorders, would get a 6% increase to $851 million.

National Aeronautics & Space Administration. The budget proposes a 15% increase for R&D at NASA in fiscal 1992 to $7.1 billion. At $2 billion, the space station is still the largest single item in the NASA research budget. But that figure is only 7% higher than last year, far short of original projections. At Congress' request, the agency is in the process of redesigning the space station to simplify it and decrease its dependence on the space shuttle.

Scientific research in space, which NASA Administrator Richard H. Truly calls a "top priority," would receive a big boost in the proposed budget, up 22% to $1.9 billion. Included are astronomy, life sciences, planetary exploration, and materials sciences programs.

NASA's Mission to Planet Earth is slated to receive $773 million in fiscal 1992, a 19% increase over last year. Its single largest component is the Earth Observing System, a series of huge satellites that would monitor a large number of Earth processes simultaneously. Included in the $336 million the Bush Administration has requested for the observation system is more than $80 million for a management system designed to cope with the massive inflow of new data expected.

Another $400-plus million in the Earth mission budget would support a variety of research programs and smaller satellites. Among those is the Upper Atmosphere Research Satellite, set to be launched in November, which is designed to study ozone depletion. And $5 million has been requested for remotely piloted aircraft that could carry research instruments into the stratosphere for weeks at a time. The concept was proposed by Harvard University chemistry professor James G. Anderson as a way to gather data crucial to understanding ozone loss and climate change.

The funds for the Earth mission in NASA's budget make up almost two thirds of the $1.2 billion the Bush Administration has proposed for global-change research in fiscal 1982. The Committee on Earth & Environmental Sciences, under Presidential Science Adviser D. Allan Bromley's Office of Science & Technology Policy, is coordinating interdisciplinary research across nine federal agencies aimed at understanding and predicting global change such as ozone depletion, greenhouse warming, deforestation, and sea-level rise.

The Bush Administration's 1992 requested funds for global change research is a 24% increase over 1991 and almost double the funds appropriated in 1990. In addition to NASA, the National Science Foundation; the Commerce Department's National Oceanic & Atmo-

Climate research funds climb since 1990

$ Millions	1992^a	1991^a	1990^b	% change 1991-92
NASA	$ 772.6	$651.6	$488.6	19%
Earth Observing System	336.0	191.0	74.0	76
Other Earth sciences programs	431.6	460.6	414.2	-6
Remotely piloted aircraft	5.0	—	—	—
NSF	118.5	87.1	55.0	36
NOAA^b	78.0	47.0	18.0	66
Energy	77.0	65.6	50.0	17
Agriculture	53.2	38.6	21.2	38
Interior	46.4	36.6	13.3	27
EPA	26.0	21.8	13.2	19
Smithsonian	7.5	5.4	—	39
Defense	6.3	—	—	—
TOTAL	$1185.5	$953.7	$659.3	24%

a Estimate. b National Oceanic & Atmospheric Administration. **Source:** Office of Science & Technology Policy's Committee on Earth & Environmental Sciences

Glossary of budget terms

Fiscal year. Year running from Oct. 1 to Sept 30. The fiscal year is designated by the calendar year in which it ends.

Obligations. Commitments made by federal agencies to pay out money for products, services, or other purposes, as distinct from the actual payment.

Outlays. Payments for obligations incurred under Congressionally granted budget authority generally made by issuance of checks on the Treasury. Outlays during any fiscal year may be for obligations incurred in prior fiscal years or in the same fiscal year.

Note: The R&D numbers from individual agencies frequently differ from those used by the Office of Management & Budget in preparing its analysis of total federal R&D funding.

spheric Administration; the departments of Energy, Agriculture, and Interior; and the Environmental Protection Agency would also receive significant funding for the program. The Smithsonian Institution and the Department of Defense are minor players.

Department of Energy. DOE's fiscal 1992 R&D budget proposal is built around the forthcoming National Energy Strategy, according to Energy Secretary James D. Watkins, and includes $653 million for DOE strategy-related R&D, an increase of $134 million, or 26%, for fiscal 1992. Over the five-year period 1992 through 1996, DOE will invest $3.5 billion in these initiatives.

This new energy R&D strategy is intended to foster a new, results-oriented approach, and not merely more of the same traditional government-funded energy R&D programs. It aims to avoid the mistakes of the past. As the budget documents point out, from 1980 through 1990 the government invested about $21 billion in energy technology R&D. But that investment has had relatively little payoff for a number of reasons. These include the inherently high risk of some R&D; poor R&D choices, such as synthetic fuels and breeder reactors; and lack of significant private-sector financial and management involvement linking R&D to successful commercial deployment.

Among the increases linked to the energy strategy are $69 million, to $314 million, for advanced electricity technology, including $178 million for advanced reactor concepts, $51 million for photovoltaics, and $22 million for superconductivity research. Research on new transportation fuels gets a $24 million increase to $113 million, including $52 million for research on advanced oil recovery, $44 million for fuels from biomass, and $17 million for alternative fuel utilization research.

On paper DOE's research on basic energy sciences is not sharing any of this budget largess; its budget is essentially frozen at $570 million. Funding for basic energy sciences' chemical program appears almost flat at $158 million, while that for materials science is apparently down 7% to $257 million.

However, all is not as it appears. Hidden in the basic energy sciences fiscal 1991 budget is $59.2 million for Congressionally directed projects for which DOE has no intention of seeking more funds. A good portion of that project money, $46.8 million, is included in the division of materials sciences fiscal 1991 budget. When factored out, the division's core programs show an increase of 12% for fiscal 1992. Research funded out of materials sciences would increase 4% to $157 million, while funds for facilities operations would rise 29% to $100 million.

DOE's division of chemical sciences has no Congressionally mandated projects hidden within its fiscal 1991 budget, neither does it have any major increase for 1992. In fact, according to DOE budget documents, the chemical sciences research budget would drop 2% to $98 million, but its facilities operation budget would rise 4% to $60.3 million in fiscal 1992. However, chemical sciences division director Robert S. Marianelli indicates the situation isn't quite so bad as it seems, though it's still not great. There is about $5.5 million available, enough to cover the cost of inflation for the division's research programs in fiscal 1992.

National Science Foundation. NSF acting director Frederick M. Bernthal started off his briefing on the agency's fiscal 1992 budget by remarking, "I must have the easiest job in the city of Washington today" in view of the "really extraordinary budget" that President Bush has submitted to Congress for NSF. And it is extraordinary. As Bernthal noted, if the 18% increase to $2.6 billion slated for NSF isn't the highest increase to any federal agency, it must be close.

Huge SSC increase skews DOE R&D funding

$ Millions	1992[a]	1991[a]	1990[b]	% change 1991-92
ENERGY R&D	**$4135.0**	**$3847.3**	**$3492.8**	**7%**
General science and research	**1542.5**	**1144.9**	**1056.2**	**35**
High-energy physics	666.4	588.7	576.3	13
Superconducting Super Collider	533.7	242.9	192.7	119
Nuclear physics	342.4	313.3	287.2	9
Basic energy sciences[c]	**569.7**	**572.5[d]**	**450.8**	**0**
Materials sciences	257.1	274.9	196.2	−7
Chemical sciences	158.3	157.6	138.5	0
Other research	154.3	140.0	116.1	10
Nuclear	**398.0**	**305.0**	**334.9**	**30**
Fusion	**337.1**	**273.6**	**316.5**	**23**
Clean coal technology	**315.0**	**391.0**	**334.9**	**−20**
Biological, environmental	**312.6**	**368.6**	**305.2**	**−15**
Conservation	**274.1**	**214.6**	**158.8**	**28**
Fossil	**184.0**	**378.8**	**393.4**	**−51**
Solar and other renewables	**202.0**	**198.3**	**142.1**	**2**
DEFENSE R&D	**2565.0**	**2506.9**	**2550.6**	**2**
Weapons R&D, testing	1764.0	1737.1	1908.6	1
Naval reactor development	801.0	769.8	642.0	4
TOTAL	**$6700.0**	**$6354.2**	**$6043.4**	**5%**

Note: Budget authority. a Actual. b Estimate. c Operating expenses. d Includes $59.2 million for Congressionally directed projects for which no funding is requested in 1992. **Sources:** Department of Energy, Office of Management & Budget

NSF chemistry division director Kenneth G. Hancock is equally pleased with the 10%, $10 million increase to $112 million slated for the chemistry division. He notes that the requested 10% increase equals the total actual increase the division has gotten since 1987. And he says that after several years of putting much needed emphasis on infrastructure issues—undergraduates, graduates, postdocs—the emphasis in 1992, as it is to some extent this year, will be on individual investigator awards. That is where the increased funds will go. The increase, he says, will go not only to providing larger grants but also to improving the success rate for first-time applicants.

Hancock points to the new $50 million instrumentation initiative as being extremely important for chemistry. That initiative aims at providing researchers with access to equipment in the $100,000 to $2 million price range, equipment that is not currently funded out of regular research grants or under the research facilities modernization program, which is being done away with in the budget request anyway. To get one of the new instrumentation grants, cost-sharing of at least 50% from nonfederal sources will be required.

NSF is also not requesting any funding for a new round of science and technology centers in fiscal 1992. However, it is requesting what officials say is enough funding to keep the current S&T centers healthy. For example, the mathematical and physical sciences directorate is requesting a 12% increase to $21 million for the six S&T centers it supports.

Department of Agriculture. At USDA, Bush is proposing $1.3 billion in R&D funding for fiscal 1992, a slight decrease from the amount appropriated in 1991. The Agricultural Research Service, the largest research agency within USDA, would increase 7% to about $717 million. But the Cooperative State Research Service (CSRS) and the forest service research both face a cut.

A large part of the decline stems from the Administration's request for less money for two programs within CSRS. Those programs, buildings and facilities construction and so-called special research grants, in the past have received funds earmarked for pet projects of Representatives and Senators. In an effort to curtail such pork-barreling, the Administration has suggested a new program of competitive grants for renovation and construction of facilities for agricultural sciences. The proposed $25 million in grants would require matching funds from nonfederal sources.

The Competitive Research Grants Office within CSRS, which administers the only grants at USDA that are distributed through a competitive peer-review process, would receive a 71% increase from 1991 levels. Bush has asked for $125 million for the office's National Research Initiative, established last year, which seeks to apply advanced research tools to agricultural problems (C&EN, Nov. 26, 1990, page 15).

"This will be a pretty good increase as long as we don't have to spread it over too many new programs," says Paul Stumpf, the research grants office's chief scientist. Stumpf remains concerned, however, about a 14% cap on overhead imposed last year by Congress and about the possibility Congress may require matching funds on all competitive grants.

NSF's total budget is up 18% . . .

$ Millions	1992^a	1991^a	1990^b	% change 1991-92
Mathematical and physical sciences	$ 650.1	$ 558.3	$ 518.5	16
Geosciences	419.5	367.7	325.0	14
Education and human resources	390.0	322.4	220.6	21
Biological, behavioral, and social sciences	355.6	315.4	293.7	13
Engineering	247.7	215.7	200.1	15
Computer and information science and engineering	229.5	186.1	169.8	23
Antarctic research	118.0	100.4	71.8	17
Salaries and expenses	122.0	101.0	96.3	21
Scientific, technological, and international affairs	61.0	51.0	47.8	20
Research instrumentation	50.0	0	0	
Research facilities modernization	0	20.5	0.4	−100
TOTAL	**$2643.4**	**$2238.5**	**$1944.0**	**18**

. . . with funding for the sciences up 12% . . .

$ Millions	1992^a	1991^a	1990^b	% change 1991-92
Ocean sciences	$ 188.5	$ 164.8	$ 147.3	14%
Physics	142.0	129.0	123.8	10
Atmospheric sciences	132.8	114.5	104.1	16
Materials research	136.6	122.6	117.0	11
Chemistry	112.0	102.1	97.9	10
Astronomical sciences	107.4	97.3	91.5	10
Mathematical sciences	79.5	72.0	69.3	10
Biotic systems, resources	78.3	70.7	66.5	11
Earth sciences	74.7	68.3	60.1	9
Cellular biosciences	67.9	61.0	57.7	11
Molecular biosciences	57.5	51.3	48.2	12
Behavioral, neural sciences	51.6	47.8	45.8	8
Social, economic sciences	41.3	35.0	32.3	18
TOTAL	**$1270.1**	**$1136.4**	**$1061.5**	**12%**

. . . and for chemical programs up 11%

$ Millions	1992^a	1991^a	1990^b	% change 1991-92
Materials research	**$136.6**	**$122.5**	**$117.0**	**11%**
Project support	80.2	69.6	66.2	15
Laboratories and groups	37.8	35.8	34.6	6
Facilities, instrumentation	18.6	17.1	16.2	9
Chemistry	**111.9**	**102.1**	**97.8**	**10**
Physical	33.0	30.1	29.0	10
Organic and macromolecular	27.7	25.3	24.5	9
Inorganic, bioinorganic, and organometallic	19.6	17.3	16.2	13
Analytical and surface	15.4	13.7	12.9	12
Instrumentation	8.1	8.1	8.1	0
Special projects	8.1	7.6	7.1	7
Chemical and thermal systems engineering	**38.2**	**33.0**	**30.8**	**16**
Interfacial, transport, and separations process	9.9	8.7	7.5	14
Fluid, particulate, and hydraulic systems	9.8	9.2	9.0	6
Chemical reaction processes	9.4	7.0	6.9	34
Thermal systems	9.1	8.1	7.4	12
Biochemistry	**16.1**	**14.6**	**14.3**	**10**
Cellular biochemistry	**14.9**	**13.1**	**12.3**	**14**
TOTAL	**$317.7**	**$285.3**	**$272.2**	**11%**

Note: Obligations. **a** Estimate. **b** Actual. **Source:** National Science Foundation

No growth in overall USDA research funds

$ Millions	1992^a	1991^a	1990^b	% change 1991-92
Agricultural Research Service	$ 716.7	$ 672.5	$ 606.1	7%
Cooperative State Research Service	409.2	454.2	385.6	-10
Forest service research	166.8	186.0	156.1	-10
National Agricultural Library	17.5	16.8	14.7	4
TOTAL	**$1310.2**	**$1329.5**	**$1162.5**	**-1%**

Note: Obligations. a Estimate. b Actual. **Source:** Department of Agriculture

Clean Air Act boosts research at EPA

$ Millions	1992^a	1991^a	1990^b	% change 1991-92
Multimedia	150.7	124.2	84.0	21%
Air	112.4	86.6	77.9	30
Superfund	68.6	73.6	78.7	-7
Hazardous waste	43.6	39.2	43.9	11
Water quality	28.9	27.7	26.9	4
Toxic substances	26.3	25.5	27.2	3
Drinking water	22.2	20.7	20.9	7
Pesticides	15.0	12.6	12.7	19
Energy/acid rain	13.7	13.6	33.3	0
Management & support	5.3	5.2	14.7	0
Radiation	4.0	4.0	3.6	0
Leaking underground storage tanks	0.8	0.8	0.7	0
TOTAL	**$491.5**	**$433.7**	**$424.5**	13%

Note: Obligations. a Estimate. b Actual. **Source:** Environmental Protection Agency

Chemical sciences rise moderately at NIST

$ Millions	1992^a	1991^a	1990^b	% change 1991-92
SCIENTIFIC & TECHNICAL SERVICES				
Research support activities	$ 37.8	$ 29.6	$ 24.3	28%
Electronics & electrical	33.6	21.3	16.2	58
Materials science	28.7	26.5	23.2	8
Physics	26.5	25.5	24.8	4
Chemical sciences	20.8	18.6	16.9	12
Computer sciences	15.0	11.8	9.4	27
Manufacturing engineering	12.6	8.3	6.2	53
Building & fire research	10.6	9.8	11.3	8
Technology assistance	10.1	9.0	7.4	12
Applied mathematics	6.1	5.8	5.6	4
INDUSTRIAL TECHNOLOGY SERVICES				
Advanced technology program	35.9	35.9	9.9	0
Manufacturing centers	10.3	11.9	7.4	-13
State technology program	0	1.3	1.3	-100
TOTAL	**$248.0**	**$215.3**	**$163.8**	**15%**

Note: Obligations. a Estimate. b Actual. **Source:** National Institute of Standards & Technology

Environmental Protection Agency. The agency's Science Advisory Board last year strongly recommended that EPA's R&D budget be doubled over the next five years so that the nation's environmental policy decisions could be made on a sound scientific basis. This year's proposal is at least a decent start at that goal, increasing by more than 13% to nearly $492 million. Almost all the increase has been in two areas.

Passage of the 1990 Clean Air Act added considerable responsibilities to EPA research. The agency says the 1992 proposed budget would provide $20.5 million just to conduct research necessary to implement the law's requirements. Some of these activities include studying ozone levels on nonattainment metropolitan areas, air pollution from mobile sources, health concerns from air toxics, and acid deposition.

The second area of significant increase is multimedia research. With a proposed increase of $26.5 million for fiscal 1992, it is the fastest growing part of EPA's program. Its growth comes from recognizing that little is understood about how complex ecological systems are affected by pollution over time. Among other items, the multimedia program provides more work on lead toxicity studies and pollution prevention research. EPA's Environmental Monitoring & Assessment Program would benefit from the increases as well, expanding its research on large regional ecosystems such as the Gulf of Mexico, Chesapeake Bay, and the Great Lakes.

National Institute of Standards & Technology. This office of the Commerce Department continues to grow very strongly. After a greater than 30% increase in fiscal 1991, NIST has a proposed budget of $248 million for 1992, a 15% increase. All of the increase would be applied to in-house work at NIST, a budget increase of 21%. Extramural programs have been cut or eliminated. The state technology program would be eliminated in the proposed budget, and funding for the Manufacturing Technology Centers cut 13% to $10.3 million.

The NIST program is to expand its ability to support U.S. industry in economically important areas such as electronics, advanced materials, computers, communications, industrial chemical technology, and manufacturing. In 1992, $22 million for new initiatives at NIST would go toward measurement technology and standards for high-temperature superconductors, intelligent machines, and fiber-optic communications systems; new security criteria for computer and telecommunications systems; and thermophysical property data needed for alternatives to chlorofluorocarbon refrigerants.

In the chemical sciences program, NIST plans a 12% increase to $20.8 million, a mild increase compared with others. Much of the focus here will be to continue to supply high-technology industries with the new measurement methods they need to produce products to an ever higher degree of specification. These include on-line optical and electrochemical sensors to reduce defective products. Other programs include, in part, measurement methods for DNA profiling and separation of biomolecules, computerized expert systems for automated control of chemical analysis systems, and ultra-thin film sensors for manufacturing control. ☐

Fourth-Quarter Drop Contributes to Lower 1990 Chemical Earnings

William J. Storck,
C&EN Northeast News Bureau

Higher feedstock costs brought on by the crisis in the Middle East and a continued soft economy cut sharply into chemical companies' earnings in the fourth quarter.

The result was a continuation of the decline for both chemical companies and diversified firms that produce chemicals. However, total fourth-quarter earnings increased from year-earlier levels for oil- and gas-producing firms and at pharmaceutical companies, although chemical results cut into the bottom line at the oil producers.

Earnings for 29 of the 30 major chemical companies regularly surveyed by C&EN dropped an average of 19% to a combined $1.01 billion, marking the sixth straight quarter of earnings declines. However, this most recent decline is the first since fourth-quarter 1989 that the decrease was not more than 20%.

Sales, however, were helped greatly by increased selling prices. Combined sales for the 29 companies rose 13% to $21.9 billion. The result of the disparity between the increase in sales and the decline in earnings was that profitablity at the companies fell rapidly. Profit margins in the fourth quarter of 1990 for the companies averaged 4.6%, compared with 6.4% in the year-earlier quarter. This is the lowest quarterly profitability level since the final three months of 1986.

However, while the drop in earnings was less than in any quarter in 1990, it was more widespread among the chemical companies surveyed. A total of 16 out of the 29 companies reported decreases in earnings in the fourth quarter, com-

Chemical industry leaders for the fourth quarter . . .

Sales				Earnings[a]			Profitability		
Rank 1990		$ Millions	Rank 1989		$ Millions	Rank 1989		Earnings as % of sales	Rank 1989
1	Dow Chemical	$5147.0	1	Dow Chemical	$274.0	1	International Flavors	13.2%	3
2	Monsanto	2202.0	2	W. R. Grace	73.8	3	Great Lakes Chemical	12.6	2
3	W. R. Grace	1946.5	4	Arco Chemical	68.0	4	Loctite	11.4	6
4	Union Carbide	1875.0	3	Air Products	60.6	8	Nalco Chemical	10.9	5
5	American Cyanamid	1133.1	5	Ethyl	58.0	5	Betz Laboratories	10.5	7
6	Hercules	820.7	6	American Cyanamid	56.5	7	Arco Chemical	9.0	4
7	Quantum Chemical	765.4	9	Union Carbide	52.0	2	Ethyl	8.6	9
8	Arco Chemical	759.0	11	Rohm & Haas	36.8	16	Air Products	8.4	12
9	Air Products	724.6	7	Great Lakes Chemical	36.6	12	Georgia Gulf	8.3	1
10	Rohm & Haas	677.7	10	Nalco Chemical	35.6	11	Crompton & Knowles	7.2	13

. . . and for full-year 1990

Sales				Earnings[a]			Profitability		
Rank 1990		$ Millions	Rank 1989		$ Millions	Rank 1989		Earnings as % of sales	Rank 1989
1	Dow Chemical	$19,773.0	1	Dow Chemical	$1384.0	1	International Flavors	16.3%	2
2	Monsanto	8,995.0	2	Monsanto	490.0	2	Arco Chemical	13.9	4
3	Union Carbide	7,621.0	3	Arco Chemical	394.0	4	Great Lakes Chemical	13.2	3
4	W. R. Grace	6,754.0	4	Union Carbide	353.0	3	Loctite	12.1	7
5	American Cyanamid	4,570.2	5	American Cyanamid	314.0	5	Betz Laboratories	11.0	9
6	Hercules	3,200.0	6	Air Products	234.8	7	Nalco Chemical	10.8	8
7	Air Products	3,146.8	10	Ethyl	223.8	6	Georgia Gulf	10.2	1
8	Arco Chemical	2,830.0	8	Rohm & Haas	206.8	10	Ethyl	8.9	10
9	Rohm & Haas	2,824.2	9	W. R. Grace	202.8	8	Crompton & Knowles	7.7	17
10	Quantum Chemical	2,656.1	7	International Flavors	156.7	12	Air Products	7.5	13

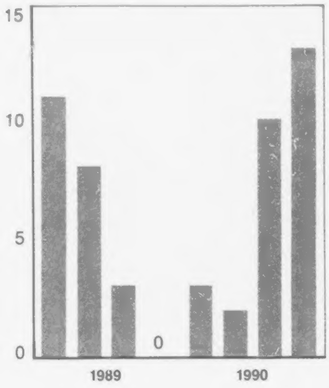
Note: Based on 30 chemical companies listed on page 20. [a] After taxes.

Chemical industry 1990 fourth-quarter results

- Sales increased 13%
- Earnings dropped 19%
- Profit margins fell to 4.6%
- Production hardly rose
- Prices jumped 5%

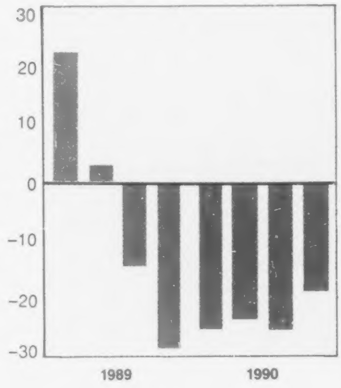
Sales

% change from year-earlier quarter



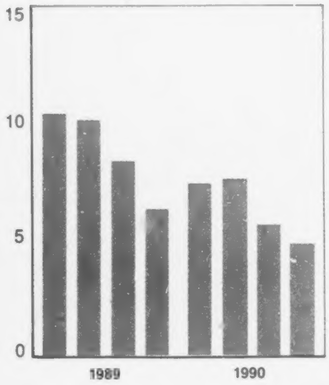
Earnings

% change from year-earlier quarter



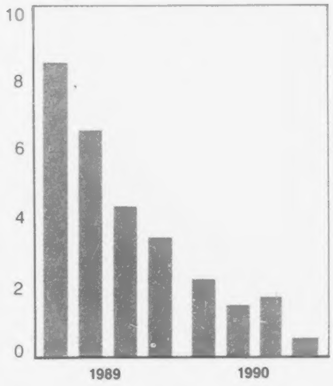
Profit margins

After-tax earnings as % of sales



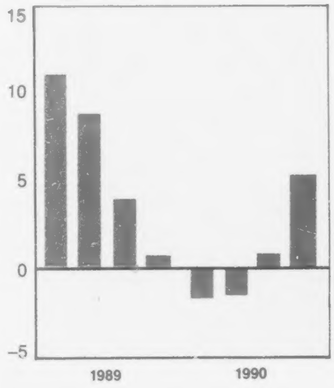
Production

% change from year-earlier quarter



Prices

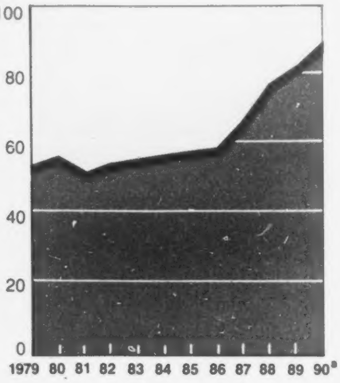
% change from year-earlier quarter



Sales in 1990 rose about 7% but earnings declined 23%, lowering profit margins to about 6.3%

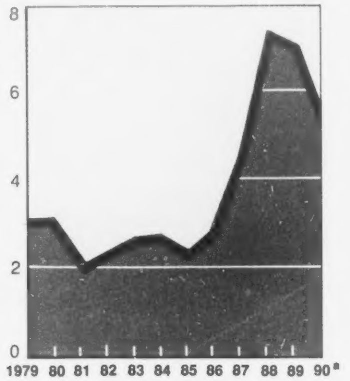
Annual sales

$ Billions



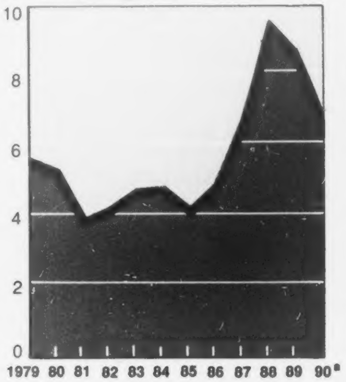
Annual earnings

$ Billions



Annual profit margins

After-tax earnings as % of sales



Note: All sales, earnings, and profit data are based on 30 chemical companies listed on page 20. a C&EN estimates.

Fourth-quarter earnings fell average of 19% for major chemical companies

	FOURTH-QUARTER 1990						FULL-YEAR 1990					
	Sales	Earnings[a]	Change from 1989		Profit margin[b]		Sales	Earnings[a]	Change from 1989		Profit margin[b]	
	($ millions)		Sales	Earnings	1990	1989	($ millions)		Sales	Earnings	1990	1989
Air Products	$ 724.6	$ 60.6	11%	23%	8.4%	7.6%	$ 3,146.8	$ 234.8	19%	14%	7.5%	7.7%
American Cyanamid	1,133.1	56.5	21	11	5.0	5.4	4,570.2	314.0	8	13	6.9	6.6
Arco Chemical	759.0	68.0	25	-9	9.0	12.4	2,830.0	394.0	6	-3	13.9	15.2
Betz Laboratories	152.4	16.0	19	19	10.5	10.5	596.8	65.5	16	17	11.0	10.8
Cabot	448.3	19.3	10	5	4.3	4.5	1,715.3	60.7	-8	21	3.5	2.7
Chemed	149.0	1.9	2	-66	1.3	3.9	599.4	16.6	1	-37	2.8	4.4
Crompton & Knowles	101.0	7.3	19	21	7.2	7.1	390.0	30.0	10	22	7.7	6.9
Dow Chemical	5,147.0	274.0	21	-36	5.3	10.0	19,773.0	1384.0	12	-44	7.0	14.1
Ethyl	676.5	58.0	5	-7	8.6	9.7	2,510.0	223.8	3	2	8.9	9.0
First Mississippi	118.4	-1.4	-10	def	def	1.0	516.8	5.0	4	-39	1.0	1.6
H. B. Fuller	203.0	8.1	7	60	4.0	2.7	792.2	21.1	5	35	2.7	2.1
Georgia Gulf	229.0	19.1	-6	-54	8.3	17.0	932.1	95.3	-16	-50	10.2	17.4
B. F. Goodrich	575.8	14.1	0	-50	2.4	4.9	2,432.6	115.8	1	-32	4.8	7.1
W. R. Grace	1,946.5	73.8	13	-12	3.8	4.8	6,754.0	202.8	10	4	3.0	3.2
Great Lakes Chemical	289.4	36.6	28	16	12.6	13.9	1,066.3	140.8	35	15	13.2	15.5
Hercules	820.7	24.5	6	def	3.0	def	3,200.0	128.1	3	24	4.0	3.3
Imcera	396.2	20.9	18	113	5.3	2.9	1,528.4	85.4	30	2	5.6	7.1
International Flavor	219.3	28.8	16	18	13.2	12.9	962.8	156.7	11	13	16.3	15.9
Loctite	143.2	16.4	18	21	11.4	11.1	555.2	67.4	17	16	12.1	12.3
Lubrizol	na	na	na	na	na	5.7	na	na	na	na	na	7.7
Monsanto	2,202.0	11.0	10	-80	0.5	2.7	8,995.0	490.0	4	-23	5.4	7.3
Morton International	470.8	30.1	15	-10	6.4	8.2	1,798.9	133.4	20	14	7.4	7.8
Nalco Chemical	325.5	35.6	15	9	10.9	11.5	1,212.3	131.1	13	9	10.8	11.2
Olin	640.0	8.0	7	-74	1.3	5.2	2,592.0	84.0	3	-32	3.2	4.9
Petrolite	82.1	3.1	9	-11	3.8	4.7	300.3	13.1	3	8	4.4	4.2
Quantum Chemical	765.4	9.7	22	-46	1.3	2.9	2,656.1	21.2	-1	-81	0.8	4.3
Rohm & Haas	677.7	36.8	9	72	5.4	3.4	2,824.2	206.8	6	17	7.3	6.6
Union Carbide	1,875.0	52.0	4	-50	2.8	5.7	7,621.0	353.0	0	-44	4.6	8.2
Vista Chemical	176.3	6.3	4	-55	3.6	8.3	725.1	50.8	-4	-51	7.0	13.6
Witco	413.7	10.6	9	-26	2.6	3.8	1,631.5	68.0	3	-13	4.2	4.9
TOTAL[c]	**$21,860.9**	**$1005.6**	**13%**	**-19%**	**4.6%**	**6.4%**	**$85,228.4**	**$5293.3**	**7%**	**-24%**	**6.2%**	**8.7%**

a After-tax earnings from continuing operations, excluding significant extraordinary and nonrecurring charges. **b** After-tax earnings as a percentage of sales. **c** For 29 companies reporting. **def** = deficit. **na** = not available.

pared with 12 companies that reported declines in both the second and third quarters in 1990.

On a quarter-to-quarter basis, combined earnings for the 29 companies in the fourth quarter dropped 12% from the previous quarter. Sales, however, rose about 2% in the same period.

Earnings declines for the first three quarters of 1990 averaged 25%. So although the fourth-quarter's 19% decline may represent a slight moderation, it didn't do much to improve the full-year earnings result. The final tally shows that 1990 earnings fell 24% from 1989 to a combined $5.29 billion. Sales for the year increased 7% to a total of $85.2 billion.

Thus, average profit margins for the year for the group of chemical companies was 6.2%, still relatively high by historical standards but down from 8.7% in the previous year. This is the lowest measure of return on sales in four years. Twelve of the companies surveyed showed earnings declines for the year.

One of the main reasons for the increased sales dollar volumes in the fourth quarter was that chemical producers were able to pass along price increases on many of their products. Although chemical prices in the third quarter were up only 1% from the same period in 1989, according to government figures, in the fourth quarter they increased 5.2% from a year earlier. And they were up 3.4% from the previous three months of last year. However, output from chemical plants did not provide much help. Government data show that fourth-quarter production of chemicals and allied products was up less than 1% from fourth-quarter 1989. And fourth-quarter production was down more than 1% from the previous quarter.

The disparity between the increased prices and increased costs was made plain by Dow Chemical, whose fourth-quarter earnings fell

Fourth-quarter earnings increased for oil and drug firms, but fell for diversified companies

	FOURTH-QUARTER 1990						FULL-YEAR 1990					
	Sales	Earnings[a]	Change from 1989		Profit margin[b]		Sales	Earnings[a]	Change from 1989		Profit margin[b]	
	($ millions)		Sales	Earnings	1990	1989	($ millions)		Sales	Earnings	1990	1989
OIL AND GAS COMPANIES												
American Petrofina	$ 1,194.7	$ 19.1	58%	41%	1.6%	1.8%	$ 3,978.2	$ 125.5	31%	5%	3.2%	3.9%
Amoco	9,187.0	538.0	35	69	5.9	4.7	31,592.0	1,913.0	18	19	6.1	6.0
Chevron	13,800.0	801.0	55	150	5.8	3.6	42,600.0	2,181.0	30	50	5.1	4.4
Exxon	35,261.0	1555.0	32	21	4.4	4.8	117,079.0	5,010.0	22	8	4.3	4.8
Kerr-McGee	1,116.0	50.3	44	26	4.5	5.2	3,682.6	150.3	23	12	4.1	4.5
Mobil	19,147.0	651.0	30	46	3.4	3.0	64,244.0	1,928.0	14	7	3.0	3.2
Occidental Petroleum	6,063.0	68.0	20	127	1.1	0.6	21,694.0	358.0	8	40	1.7	1.3
Phillips Petroleum	4,322.0	294.0	42	1076	6.8	0.8	13,603.0	688.0	10	38	5.1	4.0
Shell Oil	7,657.0	446.0	39	69	5.8	4.8	24,790.0	1,036.0	13	–26	4.2	6.4
Sun Co.	4,030.0	18.0	31	350	0.4	0.1	13,380.0	229.0	18	–17	1.7	2.4
Texaco	12,991.0	473.0	41	69	3.6	3.0	41,822.0	1,535.0	17	26	3.7	3.4
Unocal	3,379.0	118.0	19	168	3.5	1.5	11,808.0	349.0	4	4	3.0	3.0
TOTAL	**$118,147.7**	**$5031.4**	**35%**	**64%**	**4.3%**	**3.5%**	**$390,272.8**	**$15,502.8**	**18%**	**13%**	**4.0%**	**4.2%**
DIVERSIFIED MANUFACTURERS												
Allied-Signal	3,143.0	107.0	3	–7	3.4	3.8	12,343.0	462.0	3	–9	3.7	4.2
Du Pont	11,064.0	468.0	23	–3	4.2	5.4	40,047.0	2,310.0	13	–7	5.8	7.0
Eastman Kodak	5,151.0	326.0	5	24	6.3	5.4	18,900.0	1,270.0	3	18	6.7	5.9
Engelhard	657.8	21.4	5	48	3.3	2.3	2,942.2	70.3	22	14	2.4	2.6
FMC	980.5	27.1	19	–16	2.8	3.9	3,722.2	155.3	9	–1	4.2	4.6
Ferro Corp.	281.7	6.2	4	–50	2.2	4.6	1,124.8	27.3	4	–45	2.4	4.6
3M	3,280.0	295.0	11	1	9.0	9.9	13,021.0	1,308.0	9	5	10.0	10.4
NL Industries	227.3	10.5	5	–49	4.6	9.5	906.6	93.5	–9	–45	10.3	17.0
PPG Industries	1,500.0	101.4	5	0	6.8	7.1	6,021.0	474.8	5	2	7.9	8.1
Tenneco	3,881.0	130.0	0	–37	3.3	5.3	14,511.0	561.0	3	–4	3.9	4.1
Vulcan Materials	271.0	19.8	5	–16	7.3	9.2	1,105.3	120.3	3	–10	10.9	12.4
TOTAL	**$ 30,437.3**	**$1512.4**	**11%**	**–3%**	**5.0%**	**5.7%**	**$114,644.1**	**$ 6,852.5**	**7%**	**–1%**	**6.0%**	**6.5%**
PHARMACEUTICAL COMPANIES												
Abbott Laboratories	1,710.1	279.8	17	11	16.4	17.4	6,158.7	965.8	14	12	15.7	16.0
American Home Products	1,613.2	328.2	–2	8	20.3	18.6	6,775.2	1,230.6	0	20	18.2	15.3
Baxter International	2,174.0	178.0	11	28	8.2	7.1	8,100.0	40.0[c]	9	–91	0.5	6.0
Bristol-Myers Squibb	2,735.9	425.5	16	25	15.6	14.4	10,299.7	1,747.7	12	21	17.0	15.7
Merck	2,099.3	442.2	19	20	21.1	20.9	7,671.5	1,781.2	17	19	23.2	22.8
Pfizer	1,785.3	154.8	19	78	8.7	5.8	6,406.0	801.2	13	18	12.5	12.0
Shering-Plough	800.0	130.6	3	18	16.3	14.3	3,322.9	565.1	5	20	17.0	14.9
Upjohn	798.7	115.9	18	29	14.5	13.3	3,020.9	458.1	11	16	15.2	14.5
Warner Lambert	1,245.5	105.4	19	14	8.5	8.8	4,686.9	484.9	12	18	10.3	9.8
TOTAL	**$ 14,962.0**	**$2160.3**	**14%**	**21%**	**14.4%**	**13.5%**	**$ 56,441.8**	**$ 8,074.6**	**11%**	**12%**	**14.3%**	**14.2%**

a After-tax earnings from operations excluding significant extraordinary and nonrecurring items. **b** After-tax earnings as a percentage of sales. **c** Includes significant nonrecurring charge.

36% to $274 million on a 21% increase in sales to almost $5.15 billion. Frank P. Popoff, president and chief executive officer, says: "Fourth-quarter results, although lower, were not surprising, given economic weakness and soaring energy and feedstock costs that could not be fully recovered by higher prices."

Dow points out that prices increased 5% from the previous quarter, but this only partially recovered the rising energy and feedstock costs, which climbed 37%. The company also says that physical volume and operating rates were essentially flat compared with the previous three months.

Union Carbide, whose fourth-quarter earnings were off 50%, was another company caught in the vise of rising feedstock costs. Company chairman Robert D. Kennedy says that fourth-quarter operating results "continued to reflect very competitive market conditions in a softening U.S. economy, as well as higher feedstock costs during the quarter, resulting from conditions in the Middle East."

Petrochemical earnings slide in fourth quarter

Chemical earnings at major oil companies were buffeted in the fourth quarter. These operations, which are made up largely of commodity petrochemicals, produced an earnings decline of 42% for the eight companies that split out net earnings of their chemical units.

The decline, to an aggregate $388 million, would have been much worse, save for a recovery in chemical operations at Unocal.

Most of the companies that reported earnings of their chemical operations had the same complaints about business in the fourth quarter. These included primarily higher feedstock costs leading to lower profitability. In many cases, however, these higher costs for raw materials were partly offset by increased prices and higher sales volumes, according to statements from the companies.

EARNINGS ON CHEMICAL OPERATIONS

$ Millions	Fourth quarter 1990	Fourth quarter 1989	% change	Full year 1990	Full year 1989	% change
Amoco	$ 3.0	$ 79.0	–96%	$ 171.0	$ 481.0	–64%
Chevron	41.0	61.0	–33	203.0	378.0	–46
Exxon	98.0	138.0	–29	518.0	1082.0	–52
Mobil	64.0	79.0	–19	323.0	558.0	–42
Occidental Petroleum	126.0	214.0	–41	636.0	1056.0	–40
Shell Oil	55.0	84.0	–35	308.0	630.0	–51
Texaco	–10.0	15.0	def	48.0	268.0	–82
Unocal	11.0	2.0	450	41.0	49.0	–16
TOTAL	**$388.0**	**$672.0**	**–42%**	**$2248.0**	**$4502.0**	**–50%**

def = deficit.

In spite of the large decline in the quarter, only one firm registered a loss—Texaco, which went into the red by $10 million, compared with earnings of $15 million in the same period in 1989. It is interesting that all of Texaco's loss came within the U.S. Foreign chemical businesses at the company earned $3 million in the fourth quarter, the same as fourth-quarter 1989.

The fourth quarter, although down in terms of earnings, was still a little better for the oil companies than their cumulative results for the full year, when earnings from chemical operations were essentially cut in half to a total of about $2.25 billion.

Monsanto's chemicals business also felt the impact of sharply higher costs for petroleum-based raw materials. But chairman Richard J. Mahoney says he expects petrochemical prices to fall back to levels that reflect supply-demand fundamentals once the Middle East conflict is resolved.

Not all was gloom in the fourth quarter, however. Air Products & Chemicals, for instance, increased its earnings 23% to $60.6 million on an 11% sales rise to $725 million. Chairman Dexter F. Baker says the higher results in the quarter "reflect good performance in each of our business segments, particularly chemicals."

Earnings at Imcera more than doubled to $20.9 million. Chairman George D. Kennedy credited new products, capacity additions, and improved operating performance.

For the coming year, chemical executives see better times. For instance, Monsanto's Mahoney told an analysts meeting in New York City earlier this month that the company's agricultural unit is expected to rebound this year, and although the chemical unit will still be affected by a weak U.S. economy, the strategy that moved it out of commodity petrochemicals into higher value-added products will make it less vulnerable than commodity producers.

And at Air Products, Baker says, "While there is a great deal of uncertainty in the global economic outlook, we continue to expect Air Products' sales and earnings in 1991 will exceed those of 1990." □

Chemicals have role in China's economic plans

China has just issued its new five- and 10-year economic development plans. The chemical industry plays a key role, although it may have trouble finding enough investment capital to carry it out.

In a recent report in *China Daily*, Gu Xiulian, minister of the chemical industry, is quoted telling industry and government officials that the Chinese chemical industry will be concentrating on three major areas of production and development—namely, agricultural chemicals, petrochemicals, and "precision chemicals." She noted that "even though the [chemical] industry is weak in the national economy," it will invest large amounts of capital in new production facilities.

The problem of feeding nearly 1.2 billion people remains China's biggest challenge. Thus, the highest priority for the chemical industry remains fertilizers and agricultural chemicals such as pesticides. This may cause some problems in the future because this sector of the industry traditionally generates only modest profits.

In the next 10 years, Gu says, China's chemical industry will invest in a large number of fertilizer plants. These will include eight large nitrogenous plants in Sichuan, Liaoning, Jilin, and Jiangsu provinces, and in Inner Mongolia. Six large compound-fertilizer plants also will be built together with five phosphate plants that produce by-product sulfur.

By the end of the century, China also will push construction of large petrochemical projects in Jilin, Beijing, and in the Xinjiang Uygar Autonomous Zone. Coal chemical plants are scheduled to be built in Shandong and Shaanxi provinces.

The field of greatest potential profits is "precision chemicals," meaning high-tech polymers, industrial plastics, special chemicals, and products for the textile, rubber, and auto industries.

Joseph Haggin

Rising Pollution Control Costs May Alter EPA's Regulatory Direction

EPA study predicts a surprising shift to expenditures to control land pollution, and agency administrator stresses pollution prevention strategy

Lois R. Ember, C&EN Washington

The U.S. currently spends $115 billion a year, or 2.1% of its gross national product, on pollution control. By the year 2000 the cost of such protection could rise to as high as $185 billion a year (in 1990 dollars), or 2.8% of GNP, the Environmental Protection Agency estimates.

These findings are in "Environmental Investments: The Cost of A Clean Environment," a report EPA Administrator William K. Reilly sent to Congress on Feb. 1. More than two years in the making, the "cost-of-clean" report was mandated by the Clean Air Act and by the Clean Water Act, but it is likely to strongly influence the direction the agency takes in the next few years.

Concerned about the rising costs of pollution control, Reilly says the agency must "find and apply more cost-effective approaches, ... engage in negotiations and voluntary agreements to cut pollution, ... foster breakthroughs in cleanup technologies, and ... explore new ways to finance environmental improvements."

Recently the EPA Science Advisory Board has said that federal laws and programs "are more reflective of public perceptions of risk than of scientific understanding of risk." Reilly has taken this scientific sentiment to heart. And along with the just-released report, he plans to use the SAB finding as fodder for his effort to redirect agency "resources, where discretion is allowed, to the highest priority environmental risks."

One of the most surprising findings of the report is an expected shift over the next decade from expenditures to control air and water pollution to those to control land pollution. SAB, however, has concluded that pollution on land poses fewer risks than air- and water-related pollution.

Although total pollution control costs are increasing, they are doing so at a decreasing rate. The yearly rate of increase was 14% between 1972 and 1973, 6 to 8% in the mid-1980s, and is likely to fall to about 3% in the late 1990s. Despite the increases, total pollution control costs are less than half those for clothing and shoes, one third those for national defense or medical care, one fifth those for housing, and one sixth those for food.

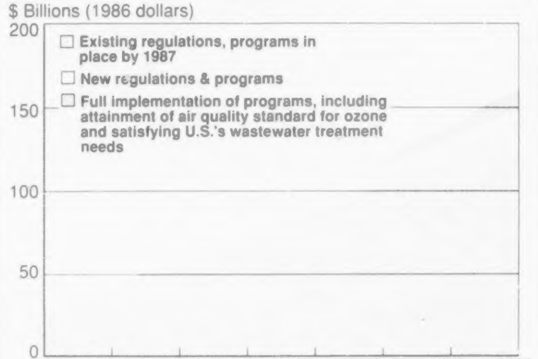
From 1980 through 1987 total costs allocated by funding source were rather stable. But from 1987 to 2000 EPA and its contractor for the cost-of-clean study, the Environmental Law Institute, project rapid growth in the federal share with corresponding cuts in all other shares, especially the private sector. The prime reason for this is the projected 140% increase in spending by the departments of Defense and of Energy to clean up military and nuclear waste.

And even though the local share percentage is expected to drop slightly in the next decade, real pollution control burdens are likely to increase for municipalities. In turn these burdens are expected to be passed along to consumers as they are increasingly asked to pay higher fees for locally provided services.

The report finds that U.S. pollution control costs as a percentage of gross domestic product appears to be higher than in several Western European countries. For example, in 1985, the latest date for which comparable data exist, the U.S. spent 1.67% of its GDP on pollution control. The comparable figure for the former West Germany is 1.52%, the U.K. 1.25%, France 1.10%, and Norway 0.82%.

According to the report's author, Alan P. Carlin, an economist in EPA's Office of Policy, Planning & Evaluation, the report has not yet been reviewed by SAB or by anybody outside the federal government. It has been circulated to other environmental and statistical agencies within the government, especially the Department of Commerce, which supplied the histor-

Fully implemented regulations could send costs soaring by 2000

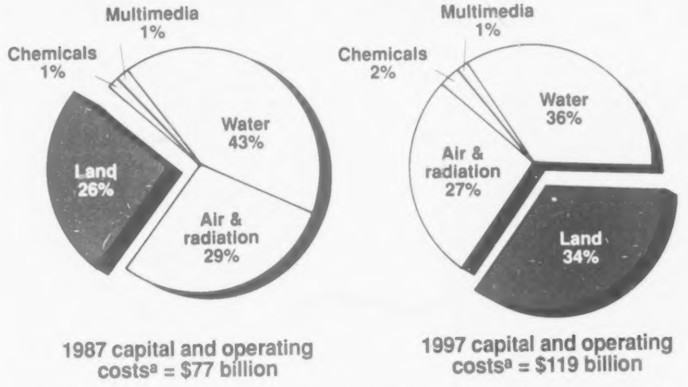


Source: Environmental Protection Agency

ical data used to make the straight-line extrapolations to the year 2000. And, of course, it had to be reviewed and approved by the Office of Management & Budget before Reilly could send it to Congress.

Governmental officials who have read the report believe it is about the best that can be obtained given the constraints—statistical and organizational. One official says the EPA study "is likely to be very much quoted and no one is likely to come up with a set of estimates that will bring EPA's into doubt."

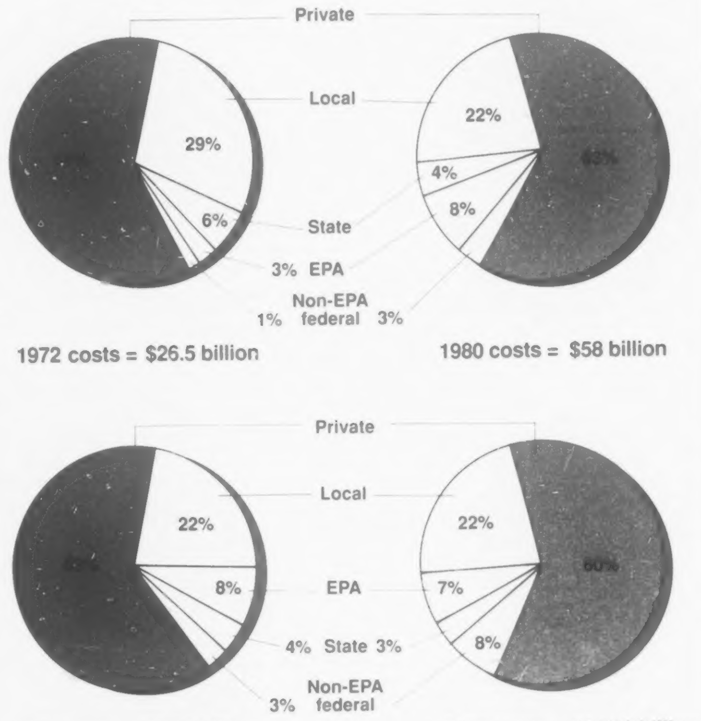
Carlin notes that Reilly "refers to the report in almost every recent speech he has given. It appears to play a prominent role in what he's thinking and where he wants to lead the agency."



Total costs to control land pollution expected to rise

a Assuming full implementation of programs, including attainment of air quality standard for ozone and satisfying U.S.'s wastewater treatment needs (1986 dollars). **Source:** Environmental Protection Agency

Clearly Reilly wants to steer his agency to what he calls "economically smart approaches to environmental protection." High on his strategic planning agenda is pollution prevention. And a subset of this is voluntary pollution reductions. Most recently Reilly called on more than 600 U.S. companies to voluntarily cut emissions of 17 so-called high-priority toxic chemicals.



Private sector's share of annual costs hovers around 60%

Source: Environmental Protection Agency

Reilly's goal is to reduce total releases and transfers of these targeted toxic chemicals by one third by 1992, and to cut them by one half by 1995. The 17 chemicals are taken from the Toxic Release Inventory. Each year the inventory reports on more than 300 toxic chemicals routinely released into the environment by some 20,000 industrial facilities.

Among the 600 companies being asked to voluntarily cut these emissions are some of the largest in the U.S. chemical industry. But other industrial sectors are also found on the list because the chemicals are used in metalworking or plating, machinery degreasing, petroleum refining, electrical and transportation equipment, pulp and paper products, furniture and instruments, as well as in the making of chemicals.

The 17 toxic chemicals have been chosen for a number of reasons—serious known health and environmental effects, a high potential for exposure, production volume, a high volume of releases, and recognized potential for cutting emissions. The chemicals targeted in EPA's Industrial Toxics Project are benzene, cadmium and its compounds, carbon tetrachloride, chloroform, chromium and its compounds, cyanide compounds, dichloromethane, lead and its compounds, mercury and its compounds, methyl ethyl ketone, methyl isobutyl ketone, nickel and its compounds, tetrachloroethylene, 1,1,1-trichloroethane, trichloroethylene, and xylenes. EPA has also targeted dioxins in its pollution prevention strategy, but they are being handled in a separate process. □

FEBRUARY 25, 1991
CHEMICAL & ENGINEERING
NEWS

Biopharmaceuticals

Market poised to expand as
products overcome
regulatory hurdles
Page 27

CHEMICAL & ENGINEERING
NEWS
FEBRUARY 25, 1991

Volume 69, Number 8
CENEAR 69 (8) 1–68
ISSN 0009-2347

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- **Chinese astrophysicist Fang Lizhi discussed human rights and scientific freedom of Chinese scientists at AAAS forum.** Page 5
- **Federal research funding was a major subject of debate at last week's annual meeting of AAAS in Washington, D.C.** Page 5
- **Effectiveness of U.S. defensive equipment, export controls, other chemical weapons issues probed at AAAS meeting.** Page 6
- **Fluoride does not cause cancer in humans, should continue to be used to help prevent tooth decay, federal study concludes.** Page 6
- **University of Wisconsin's Bassam Shakhashiri performed some chemical "magic" at AAAS symposium.** Page 7
- **More consistency in regulation of biotechnology is the aim of a report by Presidential panel.** Page 7

Cover: Amgen employee examines purification column used in production of erythropoietin

Business

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Demand for hazardous waste management is forecast to grow sharply, more than doubling by 1995. **Page 12**

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Government

Five contract labs that analyze Superfund site samples have been charged with fraud by EPA's Office of the Inspector General. **Page 14**

Former military reserves in Eastern Europe have been tagged for conservation by environmental and citizens groups. **Page 16**

Science/Technology

Parallel synthesis of thousands of chemical compounds is made possible by technology that combines synthetic chemistry and photolithography. **Page 21**

Membrane separations and hybrid systems that improve membrane technology are discussed in Department of Energy report. **Page 23**

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Product Report

With some biopharmaceuticals already available and a range of others being developed, the market is set to expand as companies continue to overcome regulatory hurdles. Page 27

Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
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Subscription Rates 1991. Printed editions: nonmembers U.S. 1 yr. $95, 2 yr. $171; outside U.S. 1 yr. $131, 2 yr. $243. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $12. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Uranium health hazard

There is a letter to the editor (C&EN, Feb. 4, page 2) that may carry adverse consequences for our war against Iraq unless prompt, proactive action is taken. This letter, from Leonard A. Dietz of Schenectady, N.Y., makes a claim that the use of depleted uranium in shells from the M1-A1 tank and A-10 attack airplane will expose soldiers and civilians involved in the Iraq war to radioactive contamination. Dietz paints a particularly dire set of possible outcomes including high doses of radiation being delivered to lung tissue from very fine particles of uranium and uranium oxide that are produced when a depleted uranium shell strikes any object after being fired.

I believe that the radiation levels discussed in the Dietz letter indicate that the dangers from the shells are far less severe. Some simple calculations illustrate the point. He claims the radioactivity level is 150 microcuries per 387 g of depleted uranium. The radioactivity would then be 3.87×10^{-1} microcuries per g or 3.87×10^{-1} picocuries per µg. Since the density of uranium is approximately 18.95, a cube of uranium 1 µm on a side (volume = 10^{-12} cc, a micrometer-size particle) would have a mass of 1.895×10^{-11} g. Therefore, the radioactivity of a single particle would be 7.33×10^{-12} microcuries. Since a microcurie is $3.67 \times 10^{+4}$ disintegrations per second, a given particle would have a disintegration rate of about 2.69×10^{-7} disintegrations per second, or about once every 0.85 year. This is a rather low level of radioactivity.

I have considerable expertise in the area of biological effects of high atomic weight radionuclides, since my Ph.D. thesis was in this area.

Gene A. Nelson
President, Biophysics Co.
Cleveland, Ohio

Quantized transition state

An account by Rudy Baum about theoretical predictions of quantized transition-state structure in the $H + H_2$ reaction (C&EN, Jan. 28, page 21) failed to mention very similar, earlier work on the $O(^3P) + H_2$ reaction [Bowman, J. M., *Chem. Phys. Lett.*, **141**, 545 (1987)]. In that paper, transition-state structure in the cumulative reaction probability was reported.

Actually, two cumulative reaction probabilities were examined: one was from exact quantum calculations [Haug, K., Schwenke, D. W., Truhlar, D. G., Zhang, Y., Zhang, J. Z. H., Kouri, D. J., *J. Chem. Phys.*, **87**, 1982 (1987)]; and the other was from approximate quantum calculations (based on a reduced dimensionality adiabatic bend theory) that I had done. The exact and approximate cumulative reaction probabilities were in very good agreement with each other, and both showed structure analogous to that reported for $H + H_2$ by Chatfield et al. [Chatfield, D. C., Friedman, R. S., Truhlar, D. G., Garrett, B. C., Schwenke, D. W., *J. Am. Chem. Soc.*, **113**, 486 (1991)] and reported in the Baum article.

Joel M. Bowman
Department of Chemistry
Emory University

Safety precautions

The chemical safety letter on a carbodiimide eye irritant (C&EN, Nov. 5, 1990, page 2) is a classic case of poor safety when dealing with chemical spills. Most responsible environmental firms insist their employees use full face respirators. Why? Ronald C. Moyer of Tuxedo, N.Y., has proven the value of eye protection from vapors as well as from physical dangers. Being donned with improper safety equipment can be as serious a blunder as taking no safety precautions at all.

James S. Smith
President/Chemist
Trillium Environmental Consultants
Coatesville, Pa.

Recruiting for science

The spectacles of the various bowl parades on television on New Year's Day raised a major question in my mind. How is it that so many schools are able to rouse so much enthusiasm for the marching bands that were a major feature in these parades? There were thousands of young people showing such a dedication to their craft that it was obvious that some force or forces were operating here that might be harnessed in other ways. One other way that will be obvious to many of your readers is in the recruitment and training of our young people in the sciences and mathematics.

It is pretty obvious that the teachers and coaches of bands and of parade discipline must be highly dedicated. Otherwise, how would they be able to arouse such interest in activities that require

Sales, Earnings of Canadian Chemical Companies Suffer in 1990

Financial results could have been worse, however, as most major firms weathered the recessions at home and in the U.S. better than expected

With both their domestic economy and their major export market (the U.S.) in recession, Canadian chemical companies limped out of 1990 in fairly good shape.

True, sales of most major Canadian chemical companies were down in 1990, particularly in the fourth quarter. Profits were down even more. But it could have been worse. Gerald P. Elden, president of Celanese Canada, called his firm's results "quite good and particularly gratifying," considering the state of the Canadian economy and the negative business environment. And Gordon R. Wittman, president and chief operating officer of Du Pont Canada, said that, despite the poor economic climate, several of his firm's products came through with higher earnings.

Those higher earnings were chalked up by such products as adipic acid, medicinals, and specialty polymers. But, they were not enough to offset lower earnings in Du Pont Canada's other product lines. As a result, Du Pont Canada's net income last year slid a hefty 28% from 1989 to $54 million, even though sales declined a minuscule 0.7% to $1.22 billion. It could have been worse had it not been for exports.

Under the Free Trade Agreement (FTA) between Canada and the U.S., tariffs on many chemical products were completely eliminated. This allowed Du Pont Canada to increase significantly its exports of several products to the U.S. In fact, the company's exports in 1990 rose 38% from the previous year to $347 million, with most of those exports moving into the U.S.

Du Pont Canada's export performance was better than that of most Canadian chemical companies. Through the first 10 months of the year (latest data available), Canadian chemical exports were up only 5%.

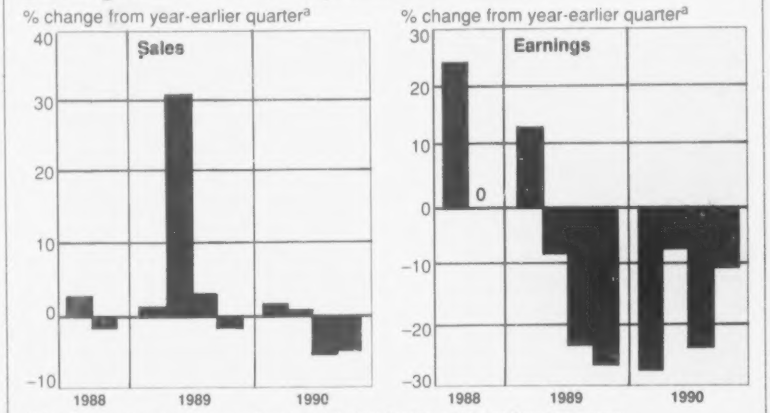
Du Pont Canada was one of the few fortunate Canadian chemical companies to enjoy a profitable fourth quarter. Although sales were down 4.6% from the year-earlier quarter to $282 million, net income advanced a healthy 23% to $8.9 million. One possible reason: higher prices on some commodity petrochemicals and plastics.

Celanese Canada, however, wasn't as fortunate in the fourth quarter. Sales were down 7.7%, but profits slid 34%. For the full year, Celanese Canada racked up sales of $316 million, down 8% from 1989. Profits, however, dropped almost 15% to $35.8 million. One reason for the company's poor fourth-quarter performance was its textile group's polyester unit. It was hit by a combination of weak markets, lower selling prices, and higher raw material costs. Weak markets for cellulosics also hurt the company's bottom line. And methanol prices were generally lower in 1990 than they were in 1989, although they did improve toward the end of the year.

Union Carbide Canada's financial results for 1990 are confusing because the company has been—and still is—undergoing a series of reorganization moves. Under the most recent proposal, parent company Union Carbide is bidding to buy the minority shares of Union Carbide Canada. It already owns 75% of the Canadian company.

This proposal supercedes an earlier plan under which Carbide Canada would have sold its chemicals and plastics business to its parent. As a result, Carbide Canada's chemicals and plastics operations were classified as "discontinued operations" at the end of last year's third quarter. For the first nine months of

Earnings continue to drop more than sales



Note: Combined results of Celanese Canada and Du Pont Canada. **a** Based on Canadian currency.

Canadian chemical companies hit rough times

$ Millions[a]	Net sales	% change from 1989[b]	Net income[c]	% change from 1989[b]	Profit margin[d] 1989	Profit margin[d] 1989
			FOURTH-QUARTER 1990			
Celanese Canada	$ 79.9	-7.7%	$ 6.8	-33.6%	8.6%	11.9%
Du Pont Canada	281.6	-4.6	8.9	22.6	3.2	8.5
Nova Corp.[e]	628.5	-13.4	87.6	140.5	na	na
Union Carbide Canada[f]	48.1	-3.9	-2.7	na	na	6.1
			FULL-YEAR 1990			
Celanese Canada	$ 316.1	-8.1%	$ 35.8	-14.5%	11.3%	12.2%
Du Pont Canada	1222.3	-0.7	54.1	-27.9	4.4	6.1
Nova Corp.[e]	2857.3	-2.1	323.4	-31.1	na	na
Union Carbide Canada[f]	216.8	6.7	7.2	-53.9	3.3	7.7

a Based on recent exchange rate of $1.00 = $1.54 (Canadian). b Based on Canadian currency. c Based on continuous operations and excluding extraordinary items. d Net income as percentage of sales. e Includes petrochemical, plastics, and rubber operations only. Nova does not break out net income by division. Income shown is operating income, which does not compare with net income of other companies. f Pending company reorganization, data include continuing operations of Linde Division only; they do not include chemicals and plastics. na = not applicable.

1990, chemicals and plastics lost $1.25 million.

Now only industrial, medical, and specialty gases remain as Carbide Canada's "continuing operations." Although sales of these products rose 6.7% last year to $217 million, profits plummeted 54% to $7.2 million.

Whether Canadian chemical companies can move into the black this year depends, of course, on the economy in Canada and the U.S. Celanese Canada's Elden says the 1991 outlook is "unpredictable." But Du Pont Canada's Wittman expects difficult economic conditions to continue well into 1991.

Earl Anderson

Hazardous waste management industry to grow

Demand for hazardous waste management, heavily impacted by environmental concerns and state, local, and federal policies, is expected to more than double by 1995. According to a forecast by Leading Edge Reports, a Cleveland-based market research firm, the $73 billion hazardous waste treatment and disposal market will grow to about $174 billion by 1995. The service sector will continue to account for about 7 to 8% of this market.

Since 1984, the demand for services such as environmental testing, consulting, analysis, transportation, and remediation has grown 21% annually to more than $6 billion in 1990. Transportation makes up more than 50% of this market, followed by consulting and engineering at 20% and remediation at 15%. Whereas 96% of hazardous waste now is treated on site by a few larger companies, as regulations broaden and become more stringent, the need for services will grow among small and medium-size companies without such capabilities. By 1995, service revenues are projected to reach $12.1 billion.

The mature land disposal market, which accounts for 75% of hazardous waste managed, is expected to grow only 2.3% annually because of stricter Environmental Protection Agency regulations. But its value will increase more than 7% annually to about $54 billion in 1995, as disposal costs rise. The amounts of hazardous waste managed through incineration, treatment (physical, chemical, or biological), and recycling are expected to more than double by 1995.

Ann Thayer

Chemical industry leads in hazardous waste output

Billions of lb	1990	1995
Chemicals & allied products	373	470
Primary metals	119	143
Petroleum & coal	88	110
Fabricated metal	68	86
Rubber & plastic	42	60
Other	71	90
TOTAL	**761**	**959**

Source: Leading Edge Reports

Spectrum Chemical opens East Coast plant

Spectrum Chemical opened its new facility in New Brunswick, N.J., earlier this month to provide fine chemicals to customers in the East. The new facility thus joins Spectrum's established unit at Gardena, Calif.

Spectrum is a privately held manufacturer and distributor of research chemicals and reagents. Since the middle of 1990, the company also has been the exclusive North American distributor for Janssen Chimica, which produces more than 12,000 organic chemicals at its plant in Belgium. Janssen Chimica is the chemicals division of Janssen Pharmaceutica, a wholly owned subsidiary of Johnson & Johnson.

Paul Berg, president of Spectrum says that the new unit, besides producing Spectrum products, warehouses more than 10,000 Janssen chemicals. Presently, it also holds about 2000 Spectrum products, which ultimately will be increased to 4000.

The East Coast facility is essentially the reverse of that in the West, which focuses more on Spectrum products and is lighter on the chemicals coming from Janssen.

Paul DiMarco, plant manager of the new facility, says that the site was chosen primarily because of the large number of pharmaceutical companies in the New Jersey area. These companies, using Spectrum's products in research, provide a good potential customer base.

In broadening its line and scope, Spectrum is going up against a number of fine chemicals suppliers, including J. T. Baker, Alfa, Mallinckrodt, Eastman Kodak, and, of course, Sigma-Aldrich, which is perhaps the largest in the breadth of its product line.

William Storck

Hybrid systems improve membrane technology

The idea of using membrane separation as a way of conserving energy is gaining more attention. To get a better insight into the strengths and weaknesses of this approach, for example, the Department of Energy has sponsored several projects aimed at promoting separations with membranes. One of these projects, just completed, was aimed at determining the broad rules for applicability of membrane separators in some of the larger industrial processes.

Membranes offer an attractive means for component separation in process streams, their appeal centering on the energy conservation possible. But they also have intrinsic limitations that restrain their usefulness as stand-alone units. Hence, economic pressures are prompting the use of membrane separators in concert with conventional separation technology. These hybrid units optimize performance at least cost.

Guidelines for designing and specifying hybrid units are only now being developed. More extensive use of membrane separators will require demonstration of their effectiveness in a broader spectrum of applications, technical education, and development of some new membrane materials.

The greatest appeal of membranes has always been their low energy consumption. The most successful high-volume applications to date have been in separation of high-volume gas stream components and desalination of seawater by reverse osmosis. There have also been numerous applications of membrane separations in clinical analysis and in specialized membrane reactors for high-value products. However, membrane separators are potentially usable in a much wider variety of industrial processing, suggesting greater application than they have experienced.

The new DOE project was carried out by Douglas E. Gottschlich and Daryl Roberts of SRI International. The final report on the project has just been issued by DOE.

The report recognizes that although membrane technology has provided a new means for materials separation, it has economic limitations. The present consensus is that membrane operations are best conducted, and are more economical, when carried out in conjunction with conventional technology. The SRI report lists the criteria for selecting a hybrid membrane system. The focus is on energy consumption of the hybrid, compared to that of membranes alone or conventional technology alone.

Largest energy users have room for savings

Industry	Energy purchased, trillion Btu
Chemicals	2630
Primary metals	2241
Pulp and paper	1262
Oil refining	1137
Stone/clay/glass	1078
Food	913
TOTAL	**9261**

Source: Department of Commerce (most recent available data)

The general methodology used in the SRI study was to consider numerous industrial separations and identify those that appeared to be amenable to membrane separations. Four particular examples were then selected for detailed evaluation. These were propane/propylene separation, removal of nitrogen from natural gas, concentration of kraft black pulp liquor, and solvent deasphalting.

All of these processes appear to be on the verge of commercial viability, and they provided the means to extract the general criteria that would apply to any hybrid system for industrial use. The criteria were then used to identify 10 separations that the investigators consider worthy of further development by DOE. The principal guides to selecting promising hybrid systems were thermodynamic and economic.

The most recent available data from the Commerce Department put total U.S. industrial energy consumption at about 11,500 trillion Btu, with roughly 80% being consumed by six industries. All employ extensive separation processes; the major conventional ones are distillation, absorption/stripping, adsorption, ion exchange, extraction, precipitation and crystallization, and filtration. The most energy-intensive of these processes involves a single phase from which two phases of different compositions must be generated. The two phases are then separated by gravity or filtration. The energy (usually heat) required to generate the phases is quite large.

The investigators noted that membranes don't usually produce high-purity products. But neither do they require phase changes, and they are particularly useful in bulk separations. Combining the membrane with more conventional technology should, in principle, provide a hybrid with optimum characteristics.

Those hybrids that demonstrated significant energy savings in a novel application, for which adequate process data were available, and which exhibited a likelihood of being commercially acceptable were considered prime candidates for the "Best-10" list in the report. In all cases the candidate process was simulated with a commercial computer program, evaluated thermodynamically on the basis of the change of availability in the process stream, the availability of the utility streams, the extent of separation, and thermodynamic efficiency. The economic process cost was defined as the cost necessary to transform feed into product.

Given that a hybrid system is technically feasible, the most important criterion for selecting a hybrid system appears to be energy con-

Ten systems are prime energy-saving candidates

System	Potential energy saving, trillion Btu per year
Propane/propylene separation	13
Natural gas dehydration	10–12
Deasphalting of oil	10
Ethane/ethylene separation	6
Sour-water stripping	6
Inorganic acid dehydration	5
Acetic acid dehydration	3
Ammonia manufacture	2
Methyl *tert*-butyl ether manufacture	1–2
Urea manufacture	1–2

sumption. The selection rule in this regard is that a membrane hybrid is unlikely to be used unless it would require at least one third less energy than a nonmembrane technology. The 10 processes recommended for further investigation reflect the importance of this criterion.

The emphasis on energy consumption in selecting hybrid systems may not be a universal criterion. Much also depends on the price of energy. Where energy is particularly expensive, there is growing evidence that stand-alone membrane systems can be successfully used over conventional separators. Such is suggested by Jimmy L. Humphrey, head of an engineering firm in Austin, Tex., specializing in separations.

Humphrey has recently returned from a trip to Japan and Europe and notes that in Europe there are at least 36 pervaporation systems now in production for dewatering alcohol mixtures. Mitsui in Japan has a new 500 kg-per-hour unit for dewatering isopropyl alcohol and at present is working on an acetone unit. Other membrane units are being used. The interest in stand-alone units, says Humphrey, is strictly economic, but the economics involve more expensive energy than that in the U.S., where energy is still relatively cheap. If cost of energy continues to increase, however, the selection criteria may change.

It remains unclear why membrane separations, either stand-alone or hybrid systems, are not more widely understood. One observer suggests that engineering education hasn't caught up with all the new unit processes and operations. If true, the problem should be corrected with time. Another believes that the tendency to "black box" training in separations technology obscures the basic character of the operations. Thus, separations can be considered as black box operations in which there are inputs, outputs, and parameters. Specifying a separation technique for a process amounts to nothing more than keying the appropriate parameters into a simulation program. This approach, while very appealing to computer buffs, doesn't provide much insight into the physical realities of the process.

Joseph Haggin

SOFTWARE/DATABASE UPDATE

Software/Database Update provides readers with information about new chemistry-related computer programs. Vendors may submit relevant press releases to Software/Database Update, Chemical & Engineering News, *1155—16th St., N.W., Washington, D.C. 20036.*

■ **Polaris** and **Enzymix** (Molecular Simultations, $35,000 to $55,000 for both programs, Circle 301) are new modules for the BIOGRAF molecular modeling program. Polaris models electrostatic and solvation free energies of proteins and other species. Enzymix models enzymatic reactions, including bond-making and -breaking, reaction trajectories, and electrostatic energies of charged groups. The programs run on Stardent and Silicon Graphics workstations. The original versions were written by chemistry professor Arieh Warshel of the University of Southern California.

■ **Structural Ceramics Database** (National Institute of Standards & Technology, $495, Circle 302) provides information on thermal and mechanical properties of silicon carbide and silicon nitride monolithic materials, used in heat exchangers, engine components, sensors, and cutting tools. It runs on IBM PCs and PS/2s.

■ **Dortmund Data Bank** (Technical Database Services, price depends on number of modules ordered, Circle 303), a database of phase equilibrium and physical property data for pure components and mixtures, is now available in a version for IBM PCs and compatibles. Databases on vapor-liquid equilibrium, liquid-liquid equilibrium, heats of mixing, activity coefficients, gas solubility, and excess heat capacity can be ordered singly or in combination.

■ **Chem-X** (Chemical Design, $8000 and up, Circle 304), a molecular modeling program, is now available for IBM RS/6000 workstations, in addition to the Silicon Graphics, VAXStation, Apple Mac II, and IBM PC versions currently offered. The RS/6000 accommodates 3-D database building and quantum mechanics calculations, with adequate graphics for small molecules.

■ **SMILES** (Daylight Chemical Information Systems, $4000 and up [single user], Circle 305), a chemical nomenclature program, is now available as a programer's toolkit for the UNIX and VMS operating systems. The program is callable from C, Fortran, Pascal, and Lisp.

■ **Chem3D** and **Chem3D Plus** (Cambridge Scientific Computing, $595 and $895, respectively; Circle 306), molecular modeling software for the Apple Macintosh, are available in version 3.0, which includes new 3-D rotation tools and other enhancements. Chem3D Plus has energy minimization and molecular dynamics capabilities in addition to all of Chem3D's model building and manipulation functions.

■ **DigiMatic** (FEB Software, $229, Circle 307), a digitizer program for the Apple Macintosh, converts charts, graphs, or plots from existing sources (like technical journals) into editable numeric data.

■ **GRA-FIT** (JR Systems, $195, Circle 308) is a 2-D plotting system for IBM PCs. Options for displaying data include 14 plot symbols, five linear regression models, and Fourier transform-based smoothing.

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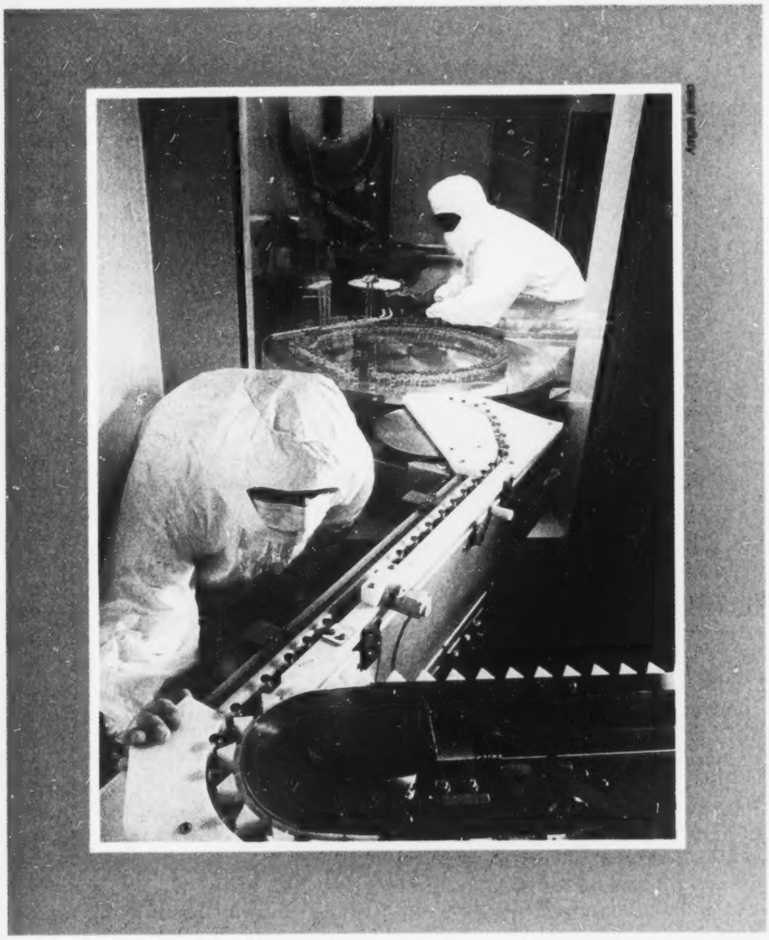
PRODUCT REPORT



Biopharmaceuticals Overcoming Market Hurdles

Ann M. Thayer,
C&EN Northeast News Bureau

Licensing, patent protection, and getting through the regulatory process have become as much a concern to fledgling biotechnology companies as developing new products.

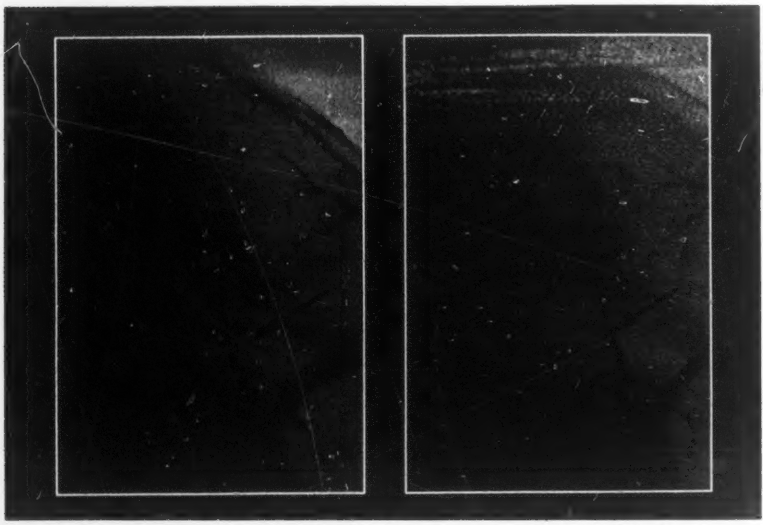
Of the products developed by biotechnology, human therapeutics have been the most important, says Roger E. Shamel, president of Consulting Resources Corp., accounting for nearly two thirds of biotechnology product sales. The Lexington, Mass.-based market consulting firm estimates that U.S. sales of biopharmaceuticals will be about $1.2 billion in 1991—a somewhat surprising statistic in light of only 12 products having made it to market.

Twelve product approvals in nearly as many years is testament to how slow movement has been. Through the 1990s, a steady stream of products is expected as companies make it past development and regulatory hurdles, expanding the market to nearly $8 billion by the end of the decade. This is because there are more than 20 applications for approval filed with the Food & Drug Administration and nearly as many drugs in the final stage of clinical studies. Although position on the regulatory ladder is no guarantee of near-term marketability, the most likely new products anticipated are a wide range of therapeutic agents with broad biological activities—colony-stimulating factors, interferons, interleukins, growth and blood factors, and monoclonal antibodies. In addition, expanded uses and second-generation versions of already approved drugs will contribute to industry growth.

Although the majority of new biopharmaceuticals now are sold by major pharmaceutical firms, experiences in bringing the first products to market have broken ground, identifying stumbling blocks for biotechnology companies that will be marketing the newer products. "There are a number of easily identified impediments to getting new biotechnology products to the market," says Richard D. Godown, president of the Industrial Biotechnology Association (IBA), "which, if corrected, would smooth the path." In addition to regulatory processes, these include issues of intellectual property protection, orphan drug law, drug pricing, and health care reimbursement.

Early beliefs that products, being based on "natural" human proteins, would be reviewed rapidly and favorably by FDA have been replaced by a degree of uncertainty, say observers. Although a few biopharmaceuticals have moved through the regulatory process as fast or faster than some traditional therapeutics, some industry executives still express frustration with FDA and the time required for product approval. The U.S. agency generally is viewed as the most cautious of worldwide regulatory groups.

A broad review of FDA is being conducted by an advisory committee to the U.S. Department of Health & Human Services, chaired by Charles C. Edwards, president and chief executive officer of Scripps Clinic & Research Foundation. In an interim report published in September 1990,



Genentech photo

Angiograms showing blood flow in blocked coronary arteries (left) indicate improvement after treatment (right) with TPA

the Edwards committee described FDA as an "agency under stress," faced with conflicting demands, limited resources, and the need for enhanced leadership and strengthened management systems. And, although finding no immediate risk to public health and safety, it believes FDA's ability to operate is being challenged by the growing number and complexity of products coming before it, coupled with increased responsibilities and lagging resources. A final committee report is due out in May 1991.

In November, Godown appeared before the committee and proposed several steps aimed at streamlining the drug approval process. At the top of his list was improving the stature and powers of the FDA Commissioner within HHS. Other suggestions were designed, Godown says, to improve resource allocation, to update existing rules and regulations, and ultimately to expedite approval of safe biotechnology products.

These suggested changes also include the deregulation of certain noncommercial clinical research and increased guidance by FDA as it becomes more familiar with biotechnology. IBA stressed that FDA should "examine all of its regulatory programs to insure that biotechnology product development is not hindered." One possible route is the approval of drugs for life-threatening conditions after Phase II efficacy trials, followed by postmarketing surveillance programs.

IBA also supports the expanded role of advisory committees in the product development and regulatory cycle. These are outside groups brought in when needed to evaluate and make nonbinding recommendations for or against approval. "It's clear that the position of advisory committees should be enhanced," says Godown, "so that when this group of outside, preeminent experts in an area suggest that something is satisfactory, they should have the burden of proof." FDA's Biological Response Modifiers Advisory Committee met for the first time last year. With several companies going before it with products, industry executives are expressing the belief that such appearances may become a regular part of the approval process.

The first biopharmaceuticals approved were human insulin and human growth hormone, genetically engineered versions of existing products isolated from animal sources. As such, says one industry executive, the transition to market was relatively easy since conceptually they were "easy sells," unlike later products to appear before FDA. Many drugs based on recombinant proteins or monoclonal antibodies are presenting FDA not only with a new technology, but often with what are unfamiliar treatment modalities to thus far unsuccessfully treated diseases.

FDA since has approved another human growth hormone, a therapeutic monoclonal antibody, two α-interferons, two hepatitis B vaccines, a tissue plasminogen activator, and a haemophilus B vaccine. In the past two years, erythropoietin (EPO) and γ-interferon were approved. Positive advisory committee recommendations have been made for two colony-stimulating factors. Biotechnology companies behind the products include Amgen, Biogen, Chiron, Genentech, and Praxis Biologics, now owned by American Cyanamid. Genentech alone accounts for five products, three of which it markets itself.

After licensing its α-interferon to Hoffmann-La Roche and insulin to Eli Lilly, Genentech went on to become the first biotechnology company to manufacture and market its own drug product. Human growth hormone (HGH), used to treat children with pituitary growth hormone deficiencies, has had double-digit annual growth and reached $155 million in sales in 1990, or about 75% of the market, says Jerry Beers, director of marketing for Genentech. The remaining market goes to Lilly's version of HGH.

Both companies have orphan drug status for HGH. The Orphan Drug Act was designed to offer incentives to companies to develop drugs for rare diseases, markets generally assumed to offer limited opportunities to recoup the high costs of drug development. The most important incentive is a seven-year market exclusivity to the first company to win approval for a drug designated as an orphan drug for a particular disease indication. Orphan drug status may be obtained for similar, but structurally different, drugs. However, clear definitions of what is meant by different have not been determined by FDA, and instead are being defined on a case-by-case basis.

One amino acid difference was enough for FDA to consider the Genentech and Lilly products as different and award orphan status to both. At least two other companies have applications pending with FDA for approval of HGH but are effectively blocked unless able to convince FDA

FDA process for approving new drugs takes many steps

Although only 12 biotechnology drugs have been approved, data compiled by the Pharmaceutical Manufacturers Association show that more than 100 genetically engineered drugs or vaccines were in clinical trials or under review by FDA at the beginning of 1990.

By the time final approval is sought, a drug product must have undergone several lengthy stages of testing and review. These stages consist of three phases of human clinical trials. First, an investigational new drug application, based on results from preclinical laboratory and animal tests for biological activity and safety, and information on drug manufacture, is filed. It becomes effective in 30 days unless denied by FDA.

Phase I of clinical trials consists of profiling the safety and pharmacological activity of a drug. Using a small number (less than 100) of healthy volunteers, not patients, Phase I trials are estimated to take less than one year to complete. Safe dosage amounts are determined as well as the duration of its action and how the drug is absorbed, distributed, metabolized, and excreted.

Phase II studies are the first step in efficacy tests on patients. Controlled studies on a population of about 200 to 300 volunteer patients are conducted along with coincident animal and human studies for safety. Such trials are expected to require about two years to complete.

With as much as 10 times the test population as in Phase II trials, Phase III trials are generally the most extensive of clinical studies, taking about three years to complete. The aim is to confirm prior efficacy results in patients afflicted with the specific disease. In addition, low-incidence adverse effects must be identified.

Upon completion of clinical trials, a product license application, as it is called by FDA's Center for Biologics Evaluation & Review, which handles biotechnology drug products, is filed. Containing all the data collected in preclinical and clinical studies, along with information on chemical structure, scientific rationale and purpose, and formulation and production details, such applications can be thousands of pages long. The FDA review and approval process takes an average of about two and a half years to complete.

Not including at least a couple years for preclinical studies, the entire clinical testing and approval process averages between seven and 10 years. FDA began a program for expedited drug approval in 1989. Its aim is to decrease the approval time for drugs for serious or life-threatening diseases. Based on promising results from Phase I, Phase II and Phase III studies may be combined for a savings of about two to three years.

Another program, which was started in 1987 in an effort to make promising investigational new drugs available to seriously ill patients early in the drug development process and before marketing approval is granted, is called treatment IND. To qualify for a treatment IND, no comparable or satisfactory therapy or drug can be available, the drug must have already completed or currently be in controlled clinical trials under an IND, and the sponsor of the trials must be seeking marketing approval. The overall review process, however, is not affected.

A company may also apply for an orphan drug designation from FDA under the 1983 Orphan Drug Act. The act was passed to encourage the development of drug products for rare diseases, defined as those affecting 200,000 or fewer individuals in the U.S. Although the drug approval process is unchanged, it provides tax incentives and seven years of marketing exclusivity to the first company receiving FDA approval for a designated orphan drug. Since the act was implemented, about 45 orphan drugs have been approved and more than 130 are in clinical testing or pending review.

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that their products, too, are different. A recently proposed FDA regulation tightening the rules would bar approval of a similiar drug unless shown to be clinically superior to one already approved (C&EN, Feb 4, page 17). A product the same or similar to an orphan drug can still be approved for other uses.

Some exceptional biopharmaceuticals, namely HGH and EPO, have attracted attention by becoming very profitable orphan drug products. Many others approved or under development have been designated as orphan drugs. Amendments to the law, proposed in early 1990, divided the biotechnology community. Although passed by Congress, the amendments were vetoed by President Bush. The debate is expected to continue.

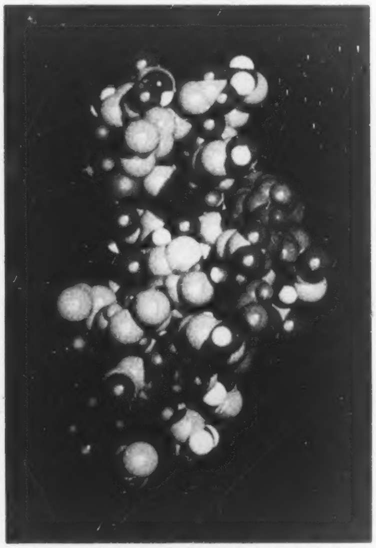
Early proposed changes sought to expand market exclusivity to those simultaneously developing products and to lower ceilings on the number of patients or on the amount of sales allowed for orphan drugs. The debate in part centers on whether companies with highly profitable products should have market exclusivity. On one side are those who believe that monopolies drive up prices and reduce availability, and that incentives already exist in what would be competitive markets. On the other side are those who say it is not possible to predict, when seeking orphan status in the early stages of investment and development, how lucrative a product will be.

The Pharmaceutical Manufacturers Association opposed changes viewed as weakening the orphan drug law, calling it "one of the most powerful incentives" in drug development and a significant factor in business decisions. Others are looking to expand the present incentives for what will probably be a majority of unprofitable orphan drugs.

"The problem with keeping the pot boiling on this issue is that it introduces uncertainty into the future of those products affected," says Godown. "This reflects on the small biotechnology companies working on orphan products, since if investors have the idea that the rules may change somewhere along the line, it becomes more difficult to attract investment." IBA opposed early amendments, which were retroactive, but supported the later modified amendments that Congress passed. Godown calls these an "honest compromise" that would have preserved existing orphan drug designations and market exclusivities.

Meanwhile, the HGH market is expected to continue to expand, says Beers, in its current treatment indication and in new areas. These include areas in which the company is conducting Phase II and Phase III trials and areas as diverse as Turner's syndrome, pediatric burns, and growth retardation related to renal insufficiency. A recent *New England Journal of Medicine* report on the effect of HGH in older adults has generated interest, but since actual long-term benefits and potential hazards are unclear, it is suggested cautiously that HGH may find some use in aiding recovery from illness or surgery.

"Growth hormone has been very successful from the standpoint of starting and running a company and providing revenues for additional R&D," comments Beers. What followed was approval in late 1987 for tissue plasminogen activator (TPA), a thrombolytic agent that dissolves blood clots and is used in treating heart attack patients. In 1990, U.S. sales of TPA by Genentech reached about $210 million, owing in part to growth of the market for thrombolytic agents. "Sales currently will probably remain somewhat level or grow slightly," says Beers. Boehringer Ingelheim, the company's licensee outside North America and Japan, has launched TPA in at least 20 countries and is now copromoting in the U.S.



Epidermal growth factor is modeled on computer at Chiron's labs

Although having about two-thirds market share, TPA has found new competition from lower priced streptokinase and Eminase, a streptokinase derivative sold by SmithKline Beecham. In March 1990, the results of a study, known as the GISSI-II trials, indicated no statistically significant difference in the performance of streptokinase and TPA. However, adds Beers, TPA was found to have fewer side effects.

The company stresses that the treatment protocol used in the study is not that favored in the U.S. Here, explains Beers, an anticoagulant and an antiplatelet aggregator are given simultaneously with TPA. There is also an ongoing debate as to whether TPA's reported ability to open more arteries faster than other agents translates into fewer deaths. At least two other trials comparing various thrombolytic agents are under way, but results are not expected for a few years.

Genentech is working actively to expand uses for TPA. An application was recently submitted to FDA for peripheral arterial occlusion, says Beers. Other possible uses being investigated in later-stage trials, if not already before FDA, are in the treatment of unstable angina, pulmonary embolism, and stroke.

The newest product for Genentech is γ-interferon. It was approved for treating chronic granulomatous disease, a rare genetic defect of the immune system that results in severe or life-threatening infections. Approved in late 1990 as an orphan drug, the company hopes to launch it in the next couple months.

"Like α-interferon, γ-interferon seems to have somewhat diverse biological actions," says Beers, "so the challenge is to follow leads with regard to biological activity and prove in the clinic that there is some value." Genentech soon will start Phase III trials for severe atopic dermatitis, he adds, and Phase III trials have been started for trauma-related infections. Although not proving to be a "magic bullet" for cancer, clinical trials are being pursued in some tumor types where activity has been seen.

Erythropoietin leads U.S. biotech drug market

$ Millions	1991	1996	2001
Cardiovascular	$ 600	$1145	$2250
Erythropoietin	350^{a}	800	1300
Tissue plasminogen activator	225^{a}	225	450
Blood factors	25^{a,b}	50	100
Superoxide dimutase	0	20	100
Others	0	50	300
Cancer	145	685	1850
Colony-stimulating factors	20^{a,b}	250	650
Interferons	125^{a}	200	350
Interleukins	0	210	550
Others	0	25	300
Hormones/growth factors	420	890	1605
Epidermal growth factor	0	65	230
Human growth hormone	250^{a}	470	650
Human insulin	170^{a}	250	325
Others	0	105	400
Vaccines	15	170	825
AIDS	0	50	300
Herpes	0	15	150
Hepatitis B, others	15^{a}	105	375
Monoclonal antibodies			
Therapeutics	20	200	490
Others	0	210	680
TOTAL	**$1200**	**$3300**	**$7700**

a C&EN estimates based on analyst reports and company projections. b Not yet approved but may reach market in 1991
Source: Consulting Resources Corp. and C&EN estimates

Other areas of development include CD4 and DNase. The human immunodeficiency virus (HIV) is believed to bind with its gp120 surface protein to the CD4 protein on immune system T cells. Genentech is testing CD4 in combination with IgG, a human antibody fragment that may enhance the activity of the receptor, in Phase I trials. Definitive efficacy markers have not been seen, comments Beers, but are not necessarily to be expected in early trials not designed to demonstrate efficacy. In early trials, the company is also investigating a recombinant form of gp120 as a potential immune system booster in HIV infected, but otherwise healthy, patients.

DNase, a recombinant enzyme, is about to enter Phase II trials, says Beers. The company plans to file for orphan drug status for DNase in treatment of cystic fibrosis. Mucus secretions in cystic fibrosis patients consist of extracellular DNA released by inflammatory cells that ac-

Good and bad news in biotechnology patents

For commercial development, scientific advances in biotechnology need to be coupled with intellectual property protection. In 1989, 935 U.S. biotechnology patents were issued in the pharmaceutical/health care area, according to a survey by the Pharmaceutical Manufacturers Association. Of those, 177 involved genetic engineering, with a sizable majority (83%) of U.S. origin and 47% from U.S. companies. Yet these make up only a small portion of biotechnology patents.

More than 7000 biotechnology patents were issued or abandoned by the U.S. Patent & Trademark Office in 1989, according to a September 1990 report by the U.S. General Accounting Office. However, the report notes, more than 18,500 applications were still pending. The sheer volume of biotechnology patent applications has made PTO's job difficult and has meant that biotechnology companies are facing long delays in gaining patent protection.

The average processing time of a biotechnology patent application, as calculated by PTO, is slightly more than 26 months, as compared with 19 months for other technologies. However, the time to process actual inventions from the original date of filing was more than 35 months, according to the GAO report. And, says GAO, decisions on genetic engineering-based biotechnology patents required about 44 months.

The GAO report concluded, "Unfortunately, despite PTO actions designed to accelerate decisions on biotechnology patents, processing delays continue for a growing backlog of biotechnology patent applications." The backlog of unexamined biotechnology patents grew 33% to about 8200 by the end of the first half of 1990, with 41% being more than a year old.

PTO has addressed the backlog and delays by increasing the number of biotechnology patent examiners. By the end of 1990, the number had risen to about 140 and is expected to increase to at least 200. Charles E. Van Horn, former head of PTO's biotechnology area and now special assistant to the commissioner, commented at ACS's national meeting last August in Washington, D.C., on the difficulty in attracting and retaining examiners, particularly in having enough experienced senior examiners to train new hires. Some training is being provided through a joint project put together by PTO, lawyers, industry, universities, and trade associations. Van Horn indicates that 1992 is no longer projected as the year in which the pendency of biotechnology patents will be reduced to the targeted 18 months. A more realistic estimate, he says, is now considered to be some time in 1993 or 1994.

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cumulate to fight infection. The enzyme appears to be effective in thinning out infected mucus, and might also find application in pneumonia, bronchitis, and emphysema.

With three products on the market, Genentech leads the biotechnology industry in having become a fully integrated biopharmaceutical company. Its experience getting there illustrates how sensitive investor outlook is, often aggravated by mismatched expectations and reality, to the ups and downs of product development.

"The consequence is to end up with one of the most successful new drugs ever introduced, but which is commonly viewed as a great failure just because it didn't turn out to be a billion-dollar drug in its third year," says Shamel of Consulting Resources. An early delay in FDA approval, a prolonged and ultimately unsuccessful patent battle overseas, and results of the GISSI-II trial hurt the outlook for TPA and caused stock prices to rise and then fall. Ironically, Genentech's products, not including those under license to others, account for nearly a third of the industry's sales.

The 15-year-old company startled the biotechnology industry with the announcement in February 1990 that Swiss-based Roche Holdings, parent of Hoffmann-La Roche, was acquiring a 60% interest in the company. Hoffmann-La Roche has connections with at least half a dozen of the upper-tier biotechnology companies as it actively licenses products. Sweetening the deal was the promise to allow Genentech to operate independently for at least a few years. Roche has an option through 1995 to acquire all remaining shares.

Genentech wanted to free itself from quarterly earnings pressures, considered at odds with long-term commitment to R&D. The Roche merger also came at a time when major pharmaceutical firms themselves were seeing the need to consolidate. Genentech's R&D spending was already about 40% of sales and its next products still had to make it through later stages of clinical trials and FDA approval. The $2.1 billion deal with Roche included nearly $500 million in capital.

Views on the merger are diverse. But, the overall impact of "losing" an industry leader thought to be able to rival major pharmaceutical firms has been significant, leaving many biotechnology companies asking whether the goal of becoming a stand-alone, fully integrated biopharmaceutical company is either desirable or possible.

Another company started a little more than a decade ago is Biogen. Like Genentech, the 13-year-old company licensed off rights to its early developments. Biogen's 1989 profitability was derived primarily from licensees' sales of five products: α-interferon, a hepatitis B vaccine and a diagnostic, γ-interferon, and β-interferon. In 1990, revenues increased 45% to $59.4 million, with about 76% coming from royalties and product sales.

Biogen licensed its α-interferon to Schering-Plough, which has a cross-licensing agreement and shares the market with Hoffmann-La Roche. In 1990, Schering-Plough's revenues from α-interferon almost doubled and are estimated at about $150 million worldwide. The product is marketed overseas with approvals in 57 countries for 16 indications.

Once expected to be a cure-all for cancer, α-interferon has been approved in the U.S. for only three diseases—hairy cell leukemia, affecting only a few thousand individuals; AIDS-related Kaposi's sarcoma; and genital warts. However, its use is expected to continue growing in at least half a dozen named uses in the areas of cancer and hepatitis. An FDA advisory committee recently recommended approval of Schering-Plough's product for hepatitis C.

Increasing royalties from hepatitis B products also contributed greatly to Biogen's growth in revenues. A license for the vaccine was granted to SmithKline Beecham, which launched its product in late 1989. Merck, a licensee of Chiron and cross-licensee of Biogen, introduced a genetically engineered hepatitis B vaccine in July 1986.

"There have been a couple of phases of Biogen," says Alan W. Tuck, the firm's vice president for marketing and business development. "There was the early science, which has been licensed off, and the income from those products is paying for its own R&D today." Strategic alliances with major pharmaceutical companies play significant roles in advancing product development by providing resources and expertise beyond research. Within the structure of an alliance, biotechnology companies may find the incentive and resources to gradually build and train their own clinical development, regulatory, manufacturing, and marketing and sales forces without having to bet company survival on the launch of a single product.

As leverage is built up through new product developments and a supporting infrastructure, there is often a progression from straight licensing deals, to licensing and supply agreements, into comarketing, and eventually to retaining proprietary products. "Where it makes sense, Biogen will continue to do business deals, particularly in some of the international markets, for a time anyway," says Tuck. "But what the company now does most of the time is retain some comarketing rights. The first focus now is to develop products for Biogen."

Through agreements with other companies, Biogen is marketing β- and γ-interferon, having cross-licensed rights to various γ-interferon patents with Genentech. Sales of Biogen's γ-interferon as a treatment for rheumatoid arthritis began in Germany in 1989 through a marketing agreement with the German pharmaceutical firm, Rentschler. In 1990, Shionogi, a Japanese pharmaceutical licensee of Biogen, launched the product for the treatment of renal cell cancer in Japan. Clinical trials are under way in the U.S. and Europe for these and other inflammatory diseases and cancer.

Whether γ-interferon will be retained by Biogen as a proprietary product in the U.S. will depend somewhat on what indication is approved first and the size of the market, says Tuck. After some early approvals, the market for γ-interferon likely will expand over the next five to 10 years, he believes, although its benefit in specific diseases, as well as dosage and treatment regimens, have yet to be determined.

Natural β-interferon is sold in Germany through Rentschler. A recombinant form has been licensed to Asta Pharma, a divison of the German chemicals and precious metals giant Degussa, in Europe outside of Germany, and is in Phase II trials for the treatment of viral infections. Biogen has retained certain comarketing rights and will supply it through its affiliate, Bioferon. In the U.S., Biogen is developing β-interferon itself and expects to enter clinical use soon as an agent against cancer and viral diseases.

Proprietary developments include hirulog, CD4, and a new program in endothelial cell receptors, which play a role in inflammatory conditions. Hirulog, a chemically synthesized peptide based on the structure of a natural anticoagulant found in the medicinal leech, is moving into Phase II trials. Potential uses include those for heart attack, unstable angina, and deep-vein thrombosis.

Recombinant soluble CD4 has been shown to inhibit in-vitro viral activity. It is moving ahead in trials, indicates Tuck, although, as others have found, it is somewhat slower than expected in showing effectiveness. According to Biogen, CD4 has been found to have no limiting toxicities and generally to be well tolerated in Phase I and II trials. "CD4 may have a place in the world of AIDS as a long-term treatment in

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combination with other products," says Tuck, such as zidovudine (AZT) or dideoxycytidine.

Undergoing an evolutionary process similar to Biogen is Chiron. In 1986 the 10-year-old company's hepatitis B vaccine, licensed to Merck, became the first biotechnology vaccine to be approved. Whereas Merck took over development, manufacturing, and marketing of the vaccine, Chiron used the basic technology in developing its diagnostics and vaccine businesses. Royalty income from the hepatitis B vaccine, with a total worldwide market of about $200 million, as well as income from its ophthalmics subsidiary and a joint diagnostics business with Ortho Diagnostics brought the company into profitability this year.

Chiron has established itself in the hepatitis C diagnostic area with a recent product approval. Hepatitis C is a high-priority research area in vaccine development for Biocine, the company's 50-50 joint venture with Ciba-Geigy. The most likely therapeutic products to reach market from Chiron are all in the 1994 to 1995 time frame, says Larry Kurtz, a spokesman for Chiron. These are a herpes simplex II vaccine, insulin-like growth factor (IGF), and antitumor necrosis factor (anti-TNF).

Anti-TNF is targeted at septic shock in which bacteria invading the bloodstream start a cascade process in the immune system. As part of this process, tumor necrosis factor, a highly toxic natural protein that can attack tumors, is released and can result in tissue damage. Anti-TNF is a natural receptor that binds to TNF to inactivate it and to help shut down the response. Anti-TNF offers an advantage in that it can deal with septic shock caused by either gram-negative or gram-positive bacteria, says Kurtz, unlike antibodies aimed only at endotoxins released by gram-negative bacteria. Anti-TNF has been licensed to Bayer and is in Phase II and III development by the Cutter Biological group of Bayer's Miles Laboratories.

Chiron has retained manufacturing rights to IGF, but has licensed to Ciba-Geigy, which is conducting clinical trials and will market it. IGF is a very general growth factor, stimulating the growth of bone, tissue, connective tissue, and muscle. Phase II trials are under way in three areas—type II diabetes to suppress the overproduction of insulin, acute kidney failure to improve kidney flow, and catabolic states as a result of trauma. A long-term goal is to investigate its use in osteoporosis and some wasting syndromes. Genentech also is testing IGF in early trials.

A herpes vaccine is being developed by Biocine and is currently in Phase II trials for use as a therapeutic. "Most people only think of vaccines as preventive," says Kurtz. "However, there is emerging evidence that you can use a vaccine approach, that is the injection of a mimic virus, in combination with an adjuvant immunomodulator to boost the [immune] response in already infected individuals." The adjuvant in this case is an immunomodulator from Ciba-Geigy called muramyl dipeptide. This approach also is being used for a therapeutic AIDS vaccine.

Results from a study in Switzerland in 1988 and 1989 for the AIDS vaccine were not definitive, says Kurtz, but encouraging enough to proceed to further trials. The vaccine has been reformulated, the adjuvant enhanced, and Phase I trials were begun in the U.S. last month. The viral part of the vaccine is a nonglycosylated version of the HIV gp120 surface protein. Genentech is conducting similar studies with a native gp120 protein, says Kurtz, and MicroGeneSys is using the gp120 precursor protein called gp160. "At this point in the AIDS area, there is nothing but therapeutic [vaccine] trials under way as nobody has yet mounted a true preventive clinical trial."

Even before Genentech's merger with Roche, the 11-year-old Amgen was emerging as a top-tier biotechnology company. With EPO, Amgen became the second biotechnology company to make the transition to a fully integrated, independent biopharmaceutical company. EPO, a naturally occurring protein that stimulates the production and differentiation of red blood cells, was approved by FDA in mid-1989 for the treatment of chronic renal failure patients on dialysis. U.S. sales currently surpass that of any other single biotechnology product.

EPO rapidly penetrated the market and now is used by more than 82,000 dialysis patients in the U.S., says Harry F. Hixson Jr., until very recently the president of Amgen. "Amgen has penetrated the U.S. market something in excess of 90%," he says, adding that current U.S. sales are more than $300 million a year. EPO is also being sold by licensees—in Europe by Johnson & Johnson subsidiary Cilag Pharmaceuticals, and in Japan by Kirin Brewery—for about another $300 million in sales.

Amgen has been embroiled in prolonged U.S. patent litigation with Genetics Institute in one of the first cases to test the scope and valid-

Genetics Institute photo

Researcher in mammalian cell culture lab helps to develop methods for scaling up production of drug products

Biotech products fit in several broad classes

Colony-stimulating factors (CSFs). Immune system growth factors that control the differentiation, growth, and activity of white blood cells. GM-CSF stimulates the production of both granulocytes and macrophages, helping to overcome immune deficiencies and fight infection. Other proteins having narrower responses include G-CSF and M-CSF.

Erythropoietin (EPO). A protein produced in the kidney that stimulates red blood cell production. It is used to treat anemia linked with renal failure and also may find use in anemia resulting from chemotherapy or therapy for AIDS.

Blood factors. Proteins involved in the multistep process of blood clotting. Some, such as Factor VIII which is deficient in persons with hemophilia A, have been isolated from blood plasma for many years, recombinant forms could offer treatments as effective and contamination-free.

Growth factors. Proteins responsible for directing the differentiation and production of various cell types. Epidermal growth factor (EGF) is expected to find use in wound healing. Platelet-derived growth factor (PDGF) is involved in collagen deposition in tissue repair. Insulinlike growth factor (IGF) has fairly broad activity in promoting tissue growth and is being investigated for nutritional and growth disorders.

Human growth hormone (HGH). A hormone secreted by the pituitary gland used to treat growth deficiencies in children. Recombinant HGH is purer, less costly, and more available than isolated natural versions.

Interferons. Broad-acting agents, produced by a variety of cells, that interfere with viral infection and may control the spread of some cancers. α-Interferon's use is expanding in the treatment of various cancers and is being investigated for use in AIDS therapy. Also under study are γ- and β-interferon for use in AIDS, cancer, and some infectious diseases.

Interleukins (ILs). Immune system hormones, or cytokines, that stimulate and regulate the growth and function of a wide variety of white blood cell types. At least 10 interleukins have been discovered. IL-1, IL-2, and IL-3 lead in development in diverse areas such as cancer, wound healing, immune deficiencies, and AIDS.

Monoclonal Antibodies (mAbs). Antibodies that are specific to certain antigens or cell types; can be used in several ways. Naked mAbs can directly attack foreign toxins, viruses, or cancer cells. mAbs also can be used to deliver radioisotopes (as therapeutics or imaging agents) or other drugs to specific targets.

ity of patents related to recombinant and natural proteins. Amgen holds patents to genetic sequences, vectors, and host cells for producing recombinant EPO. Genetics Institute holds a patent to the purified protein. In late 1989, claims of both patents were found to be valid and infringed by the other party. With an apparent stalemate, a cross-license between the two firms was ordered by the court. In early 1990, both companies appealed and hearings were held later in the year. These are expected to result in a ruling from the appeals court at any time.

Directly related to the dispute between Amgen and Genetics Institute are issues of orphan drug status and patent protection, which became focuses of the biotechnology industry this past year. In 1990, two bills were proposed by Rep. Rick Boucher (D.-Va.) aimed at increasing protection against foreign infringement. These bills sought to override a precedent that was set in a case involving a production process for carbamate pesticides. In that case, it was found that a process may be considered obvious and unpatentable even if it employs or produces a novel and unobvious (patentable) material. Thus, as biotechnology or any technology matures, obtaining process patents becomes more difficult.

"There is a great need for increased intellectual property protection for the biotechnology industry," says Hixson. "There are certain aspects of process patent case history that were developed for older technologies that are being applied inappropriately to biotechnology."

Under U.S. law, a product made abroad and imported into the U.S. cannot be stopped unless it violates a valid process patent, even if it is made with a patented material. Genetics Institute's licensee, Chugai Pharmaceuticals, was not found to infringe Amgen's patents and is able to make EPO abroad, import it, and sell it in the U.S. Patents covering genetic sequences and host cells used in producing recombinant proteins have not been interpreted as process patents, explains Hixson.

IBA has supported changing patent law, believing it's needed to help the U.S. maintain its competitive stance in biotechnology, and will "try very hard in the 102nd Congress to bring that about," says Godown of IBA. "Patents are the very lifeblood of biotechnology," he adds. "Not only do they spell protection, but they spell the ability to raise capital, make business plans, build manufacturing facilities, market, and build a company."

The former chief executive officer of Cetus, Robert A. Fildes, called the proposed changes unnecessary, protectionist, and destabilizing by virtue of the uncertainties that would be introduced into the industry. IBA's position on the Boucher bills, and its initial opposition to amendments in the Orphan Drug Act, caused Cetus and Genetics Institute to resign from the trade association.

The Amgen/Genetics Institute dispute is complicated further by Amgen's having orphan drug status and effectively blocking Genetics Institute with an application pending for the same indication. "There are a few drugs, and [EPO] is one, where the criteria still permit a reasonably high revenue base," says Hixson. "But the law itself is very sound and offers appropriate incentives to a number of manufacturers and a number of important drugs have been developed with that strictly in mind. The law is there, it's in place, and you must be prudent and take advantage of those laws so that someone doesn't use them to take advantage of you."

Genetics Institute's EPO is being sold for dialysis patients in both Japan and Europe by licensees Chugai Pharmaceuticals and Boehringer

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Mannheim, respectively. The company began petitioning FDA about two years ago with requests for approval under the Orphan Drug Act.

In a decision early this year, FDA denied two claims that related to the patient population for EPO. However, two other claims remain open. One centers on Genetics Institute's product being kept off the market, when the company holds a valid and infringed U.S. patent, by another product because of orphan status. Congress' intent in establishing orphan drug law, says Genetics Institute, was that patent law should have precedence in the event of such a conflict. In response, FDA has indicated that in the absence of a definitive decision on patent rights pending outcome of the appeals, no decision could be made.

The other outstanding claim relates to the question of whether the two products can be defined as different under orphan drug law. "It's clearly been reported that the actual carbohydrate structures of the two forms of EPO are different," says L. Patrick Gage, executive vice president of Genetics Institute. Very simple changes or deletions in the carbohydrate structure, which can depend on whether a protein is produced in bacterial, yeast, or mammalian cells, can completely inactivate the molecule, he explains. "But there is debate about how important other changes might be, like those clearly present between the two molecules."

Most of the market expansion for EPO will come about through new uses. Amgen's U.S. licensee, Ortho Biotech, just received its first U.S. approval for EPO in the treatment of AIDS-related anemia and expects to launch the product this month. Ortho and affiliated Johnson & Johnson companies hold the rights to most indications in the U.S. and to all worldwide, marketing EPO in 43 countries. A very large market for which Ortho hopes to file applications both inside and outside the U.S. in 1991 is anemia associated with cancer and chemotherapy. Other areas being looked at include anemia in predialysis patients and rheumatoid arthritis, and autologous blood donation.

Despite its record sales, EPO actually offers a limited opportunity for

Immunex technician checks product

Amgen because it retained only U.S. manufacturing rights and the U.S. dialysis market. The firm's next major product will be one of the colony-stimulating factors (CSFs), a new class of drugs that play a role in white blood cell production. CSFs are finding application in a wide variety of diseases, targeted primarily at increasing the ability of the immune system to fight infection.

Amgen filed an application with FDA in late 1989 for a CSF that promotes the production of granulocytes (G-CSF) as an adjunct to chemotherapy in correcting deficiencies of white blood cells called neutrophils (neutropenia). With a very rapid turnaround, G-CSF was recommended for approval by an FDA advisory committee in December 1990.

U.S. sales of CSFs are expected to be $200 million by the mid-1990s and $650 million or more by 2001. Amgen's initial U.S. cancer market for G-CSF is expected to be large. However, the importance of G-CSF is more than just its potential sales, Hixson says. The company has kept full marketing rights in the U.S., Canada, and Australia, and comarketing rights in Europe with Hoffmann-La Roche for a five-year period, after which Amgen has the right to assume all marketing itself.

Early in 1990, Amgen and Hoffmann-La Roche filed jointly in Europe for approval of G-CSF. The European regulatory group, the Committee for Proprietary Medicinal Products (CPMP), issued a favorable opinion on G-CSF this month. Amgen hopes that it will be followed by a series of approvals in the individual European countries throughout the year. Licensee Kirin also filed in late 1989 for approval in Japan. As with other broad-acting biological response modifiers, G-CSF is expected to expand into other uses. Amgen has active clinical programs in the areas of bone marrow transplants, chronic neutropenias, and preclinical work looking at G-CSF's antiinfective or antibacterial properties.

Amgen's R&D spending approaches 30% of sales, according to Hixson. The money is being used in part to develop tissue growth factors, two neurotrophic factors, and another early-acting blood cell growth factor called stem cell factor (SCF). Preclinical studies on SCF have shown that it may find use in treating bone marrow damage, and Amgen is trying to get it into clinical trials as soon as possible.

The tissue growth factors include epidermal growth factor (EGF) and platelet-derived growth factor (PDGF) for use in wound-healing applications. Chiron also has EGF and PDGF in Phase II trials. Both companies indicate that clinical trials have been somewhat more difficult than expected and that it will take time to develop drug delivery systems.

Direct competition for Amgen's G-CSF is expected from Chugai Pharmaceuticals, which, says Hixson, has a filing for G-CSF in Japan. Chugai is conducting clinical trials in Europe, but has not initiated any activity in the U.S., he adds. Initial competition in the U.S. and Europe is primarily expected from another CSF that stimulates the production of granulocyte and macrophage (GM-CSF) white blood cells.

Genetics Institute granted a worldwide license for GM-CSF to Sandoz, which in turn established a codevelopment and comarketing agreement with Schering-Plough. An interference has been declared by the U.S. Patent Office between patent applications filed by Genetics Institute and Immunex. Genetics Institute indicates that it was on the basis of its patent position that Schering-Plough took a cross-license. Immunex also considers itself to have a strong position.

Genetics Institute's GM-CSF is awaiting approval in the U.S. as an adjuvant to chemotherapy and, according to the company, its licensees had a closed session review with the Biological Response Modifiers Advisory Committee in December. As a broad-acting immune system stimulator, GM-CSF is under development by both Genetics Institute and its licensees and Immunex for several diseases.

Although considered a major biotechnology company, Genetics Institute has not yet marketed a proprietary product in the U.S. Its licensee, Baxter Healthcare, has filed an application with FDA for approval of Factor VIII, the blood-clotting factor deficient in individuals with type A hemophilia. A few years ago, Genetics Institute and Genentech, with its licensee Cutter Biological, cross-licensed both patents and orphan status for Factor VIII. The recombinant forms are expected to enter an already large market, offering an alternative to plasma-derived Factor VIII.

Genetics Institute's first proprietary product, having retained all U.S. and European rights, is macrophage colony-stimulating factor (M-CSF). This product is cross-licensed in a royalty-free agreement with Cetus. For different uses, says Gage, it is in Phase I or Phase II clinical trials. Three areas under investigation in which M-CSF might be useful in stimulating immune system defenses are infectious diseases, hypercholesterolemia, and cancer.

In 1990, Genetics Institute spent about $61 million on R&D. The company has started an active program in bone morphogenetic proteins (BMPs), which stimulate the formation of bone and cartilage. Preclinical work to be reported on this year is going to be "quite dramatic," Gage says, and will draw attention to what he sees as a new wave of potential products, expected to be useful in a wide variety of orthopedic, surgical, and dental conditions. One bone growth protein, BMP-2, is expected to enter clinical trials in late 1991 or early 1992. The company has kept worldwide manufacturing rights and North American marketing rights while setting up a U.S.-based development partnership and a 50-50 joint venture in Japan with Yamanouchi Pharmaceuticals.

According to Genetics Institute, it has stopped work on TPA and is evaluating further development of its second-generation product, novel plasminogen activator (NPA) in the U.S. and Europe. In a patent dispute with Genentech, a jury found in April that Genetics Institute and Wellcome infringed Genentech's TPA patents. However, the companies are awaiting a judgment not withstanding the verdict in that case. "One should expect an appeal of that judgment if it goes against us," says Gage.

Broad interpretation of the patent claims of Genentech's included second-generation molecules such as NPA, which differs from TPA by a number of deletions in the amino acid sequence. Such modifications in amino acids and glycosylation are designed to alter the activity, side effects, and immunogenicity of proteins. Genetics Institute had licensed NPA to Wellcome in 1989. In May, following both the jury verdict and the results of the GISSI-II trial, Wellcome decided to drop development.

Immunex may be in the best position to provide competition for CSF products. Having recently received a positive recommendation for approval from the Biological Response Modifiers Advisory Committee, Immunex could reach the market first with GM-CSF, but only for a limited disease indication. It has obtained orphan drug status for use in bone marrow transplant patients, but most companies, including Immunex, suggest that this will not be a significant factor in blocking the market—GM-CSF is expected to find use in several diseases. The timing of entry to the market may be advantageous in gaining product acceptance and market share. And, once approved, physicians are free to prescribe a drug for conditions outside the approved indication.

Immunex filed a product license application in February 1990 under a program for expedited review and only six months later had its first appearance before the FDA committee. Although initially it did not receive a positive recommendation, the company was allowed to make GM-CSF available to seriously ill patients under a treatment investigational new drug application. By December 1990, at a second meeting, Immunex was able to provide enough supporting data for the committee to recommend approval.

"Immunex has been fairly pleased with the way [FDA] has responded to our application. It was submitted less than a year ago and here [Immunex is] on the verge of an approval," says John A. Spears, vice president and director of sales and marketing at Immunex. "That's pretty fast in the scheme of things." Based on experience in the drug industry, the time from recommendation to approval can be anywhere from three to six months, he adds, but it is impossible to speculate if and when approval will be granted. Immunex and its partner Hoechst Roussel will comarket GM-CSF under different brand names in the U.S.

Ten-year-old Immunex has remained focused on immunological therapeutics and the launch of a first, proprietary product (C&EN, Dec. 17, 1990, page 8). Its broad area of development includes interleukins (ILs), immune system hormones directing cell growth, many of which it has in clinical trials. The company also has a very active, although still preclinical, program in interleukin receptors, which may find use in controlling certain inflammatory conditions.

Immunex has IL-1β in Phase II trials for wound healing, IL-1α in Phase I as a bone marrow protectant in radiation or chemotherapy, and IL-4 in trials for cancer therapy. IL-2 has been licensed to Hoffmann-La Roche, which has its product in clinical trials for renal cell cancer and melanoma. Currently in Phase I trials is IL-3 for neutropenia and platelet deficiencies.

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Combinations of interleukins and CSFs have been attracting attention. Immunex has developed a fusion molecule of IL-3 and GM-CSF that has shown promising in-vitro results, says Spears. However, Genetics Institute holds patents to IL-3, licensed to Sandoz and in Phase I and II trials in the U.S. and Europe, said to cover first- and second-generation molecules including "IL-3 proteins produced using all or part of the IL-3 DNA sequence and showing IL-3-like properties."

Whereas Immunex responded favorably to the FDA advisory committee's questions, the final outcome on Cetus' late-1988 application for IL-2, the first much hyped, but yet unproven, interleukin to come before the agency, is unknown. Cetus' experience, as well as first-time experiences of other biotechnology companies, is being closely scrutinized for insight into the regulatory process. At the same meeting with Immunex in July 1990, the Biological Response Modifiers Advisory Committee did not recommend for or against approval for IL-2 in the treatment of renal cancer.

"The committee asked the company to work with FDA and identify subsets of patients who were more likely to show a clinical response to the drug, and less likely to suffer severe adverse events," explains Ed Kenney, director, biological therapeutics, for Cetus. IL-2 has rather toxic side effects and a mortality rate of a few percent, not unlike other chemotherapeutic treatments. In addition, a response to IL-2 is seen in about 20% of patients, with only a few percent showing complete remission. These conflicting facts complicate the issue because IL-2 is the only drug to have ever shown any lasting activity in otherwise fatal renal cell cancer, he adds.

The company faced at least two problems regarding its clinical trial data. Because a life-threatening disease with no existing treatment was targeted, explains Kenney, it can be difficult to design a placebo-controlled, double-blind study that is preferred by FDA. Instead historical comparisons, which have been used before, to β-interferon trials on kidney cancer patients were submitted. Supporting data for IL-2 used in combination with lymphokine-activated killer (LAK) cells was not accepted by the committee. LAK cells are disease-fighting white blood cells isolated from a patient, grown in the presence of IL-2, and then reinfused. FDA has not defined how it will approach activated cellular therapies that have been described as both drugs and delivery systems.

The advisory committee's response was damaging. Market estimates for IL-2, whether realistic or not, once ran as high as several hundred million dollars, but now are more conservative. Shortly after the committee met, the company's stock dropped from just over $22 to about $8.00 per share. Shareholders also filed suit regarding disclosure about IL-2's efficacy, and its potential for FDA approval and sales. In the wake of events, Cetus chief executive Fildes resigned, and the company reduced staff and cut costs.

Cetus clearly leads in the development of IL-2 as the only company with an application pending in the U.S. and having received approval in nine European countries for renal cell cancer. Industry executives explain that it is not uncommon for products to be approved faster in Europe, which has been called a less harsh regulatory environment, than in the U.S.

Long ago cross-licensed in agreements between various companies, IL-2 is in Phase III trials for various cancers and in early trials for AIDS by Cetus and others. IL-2 plays a central role in activating T cells, which are a fundamental part of the immune response, Kenney says, and has shown activity in several broad areas including cancer and some infectious diseases.

The possible first approval of IL-2 in the U.S. has been delayed at least several months. Cetus has been working with FDA, but has not been scheduled to meet again with the advisory committee or FDA to dis-

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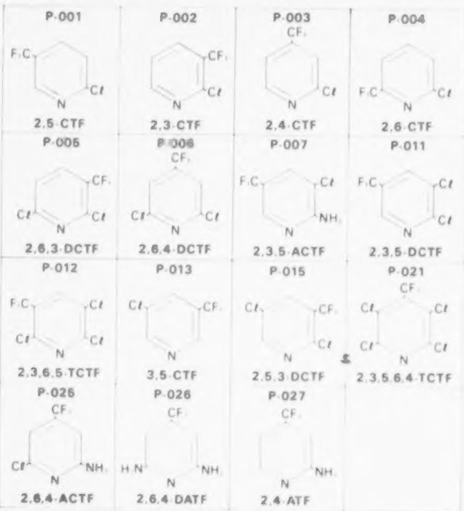

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cuss approval. "Cetus believes it has identified [those] groups of patients," says Kenney. "It will be up to us to convince FDA and/or the advisory committee."

The 20-year-old Cetus long appeared to be betting its financial success on IL-2 as its first proprietary U.S. drug product, and winning approval is still a priority. The company has spent nearly a decade and more than $100 million on developing IL-2. In the fiscal year ending June 1990, the company reported a net loss of nearly $62 million on revenues of about $39 million. The company had been investing heavily in regulatory development, and in setting up its manufacturing and marketing efforts for IL-2.

Sales of IL-2 in Europe have been growing, Kenney says, and the company is seeking to expand IL-2 into other uses. A European filing for melanoma is being prepared. Cetus also has entered into a European copromotion agreement with Hoffmann-La Roche for IL-2 and α-interferon, which find use in combination, including subcutaneous use.

"The future of IL-2 is in being used in [new indications]," says Kenney, "and it will come to be used in combinations either with other naturally occurring products or very likely with chemotherapy." Cetus also has a "second-generation" IL-2 that has polyethylene glycol molecules attached, in clinical trials for cancer and possibly in AIDS. "The animal data suggested that it did improve the therapeutic index; in other words, there was an increased efficacy and a reduced toxicity," he says. "And that's what we hope to see in humans."

After IL-2, Cetus has no major products nearing the market in the short term. The company has dropped development of a second immunotoxin that was in clinical trials—work on an earlier one was halted a few years ago—because of problems with toxicity. Tumor necrosis factor, a toxic and somewhat difficult to work with immune system agent effective against tumors, has also been dropped.

Longer term products with promise for Cetus are M-CSF, which has shown antiviral, antibacterial, and antifungal activity preclinically, and also appears to have use in cancer and possibly in wound healing. The company is making the difficult strategic decision of which indications to pursue, Kenney adds. M-CSF is about to enter Phase II trials for fungal infections.

The company also has a monoclonal antibody (mAb) for use in sepsis and septic shock patients. Cetus will face very strong competition from Xoma and Centocor, two companies focused on monoclonal antibodies that have both filed product license applications for products for sepsis. "It [will be] a competitive area," says Kenney, "but I draw the analogy with the antibiotics market—a very competitive area, but also a huge commercial area. And, if they follow anything like antibiotics, there will be some niching or positioning of them differently based on where they work."

Centocor is preparing for the launch of its mAb product, which binds to and inactivates endotoxins produced by gram-negative bacteria, the cause of about two thirds of sepsis cases. An application was filed with FDA in September 1989, shortly thereafter followed by a filing with the CPMP in Europe. "Sepsis and septic shock are very similar severe illnesses where people deteriorate very rapidly," says Elizabeth E. Tallett, executive vice president of Centocor and president of its pharmaceutical division. "Most patients are treated presumptively (before the causitive agent is known), so that market would largely be open to us as a total market."

With as many as 400,000 patients, the U.S. market has been estimated at several hundred million dollars. The only existing therapy is treating the bacterial infections with antibiotics that are not always effective in preventing what can be an extremely rapid progression to shock. Depending on the severity, low-level septicemia and sepsis patients have a mortality rate of about 25%, increasing to about 75% for those who have progressed to septic shock. In combination with antibiotics, mAbs can "sponge up" endotoxins while antibiotics work to kill the bacteria, improving the mortality rate in the most ill group by 50%.

Tallett says the company is confi-

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dent of being the first to market in Europe, and very hopeful of being the first to market in the U.S. Centocor's prime competitor, Xoma, has also developed a mAb product for sepsis and has filed applications with its partner, Pfizer, in both the U.S. and Europe. Xoma will be backed by the marketing power of a major pharmaceutical firm, whereas Centocor plans do its own marketing in both the large U.S. and European markets.

Xoma holds a U.S. patent covering the therapeutic use of mammalian source antiendotoxin mAbs in the treatment of humans having gram-negative sepsis and/or septic shock. The company's patent infringement suit against Centocor will go to trial in July, says Patrick J. Scannon, president of Xoma. Tallett says Centocor is extremely confident of having a very strong patent position.

Xoma's product is a murine mAb. According to Tallett, Centocor's is the first human mAb developed for the market and produced on a large scale. The mAbs also may be "humanized," where human segments replace some (a chimeric antibody) or most (fully humanized) of the immunoglobulin structure of a murine mAb.

Tallett says the Centocor product offers advantages in being nonimmunogenic, since murine mAbs may cause an immune response in humans. "It also has considerable benefit in terms of the effectiveness—the bottom line is 'human works better in humans,' " she says.

Scannon of Xoma believes immune reactions will not be a significant factor in treating sepsis. "If [patients] do develop an immune response [to the murine mAb], it occurs after the treatment is over and is not associated with any side effects," he explains. Most surviving patients make their own endotoxin antibodies and will only ever have one episode of gram-negative sepsis in their lives. "So it will have no effect on the first course therapy and, if you are in the vast majority of patients—something like 95% or more—who will not have a repeat course of therapy, it is not an issue."

These would be the first therapeutic products for either company. Along with marketing partner Ortho Biotech, Xoma has filed an application with FDA and is preparing one in Europe for a mAb, CD5, for use in graft versus host disease. CD5 is a murine mAb chemically linked to an enzyme, Ricin A chain, which can bind to and eliminate T lymphocytes. As with other targeted therapies Xoma is developing, the mAb is a delivery system that allows the enzyme not only to be effective but also site specific.

In graft versus host disease, the goal is to remove mature lymphocytes found in donor marrow that will attack the host body, explains Scannon. Immature immune cells in the transplanted marrow can become tolerant of the host environment. It is currently an orphan drug indication with about 3000 to 4000 transplants per year, but Scannon expects the market to grow rapidly. "The most fundamental reason is that if you can control graft versus host disease, [then] bone marrow transplantation works. . . . It's becoming a true therapy for the treatment of leukemias and a number of other blood-borne diseases."

Xoma has retained manufacturing and marketing rights to CD5 for a number of other diseases mediated by T lymphocytes. For example, Phase III trials are about to start in rheumatoid arthritis. Ortho, which already sells the only mAb product approved—one to prevent kidney transplant rejection—is involved in developing CD5 for organ transplant rejection and another yet unnamed indication. "That is an area [where] Ortho has a great deal of expertise," says Scannon, "and one that Xoma was not going into. So Xoma's relationship with Ortho has actually expanded its opportunities."

Although also developing and selling mAb-based imaging agents, Centocor's next nearest-term therapeutic is a chimeric mAb fragment that acts as a platelet aggregation inhibitor. It is in early clinical trials for use with thrombolytic agents in heart attacks, to prevent reocclusion and restenosis after balloon angioplasty, and in treating unstable angina. Centocor also is investigating anti-TNF and anti-CD4 antibodies, for possible use in autoimmune conditions such as rheumatoid arthritis and multiple sclerosis, and another directed at gastrointestinal cancers either alone or in combination with radioactive isotopes.

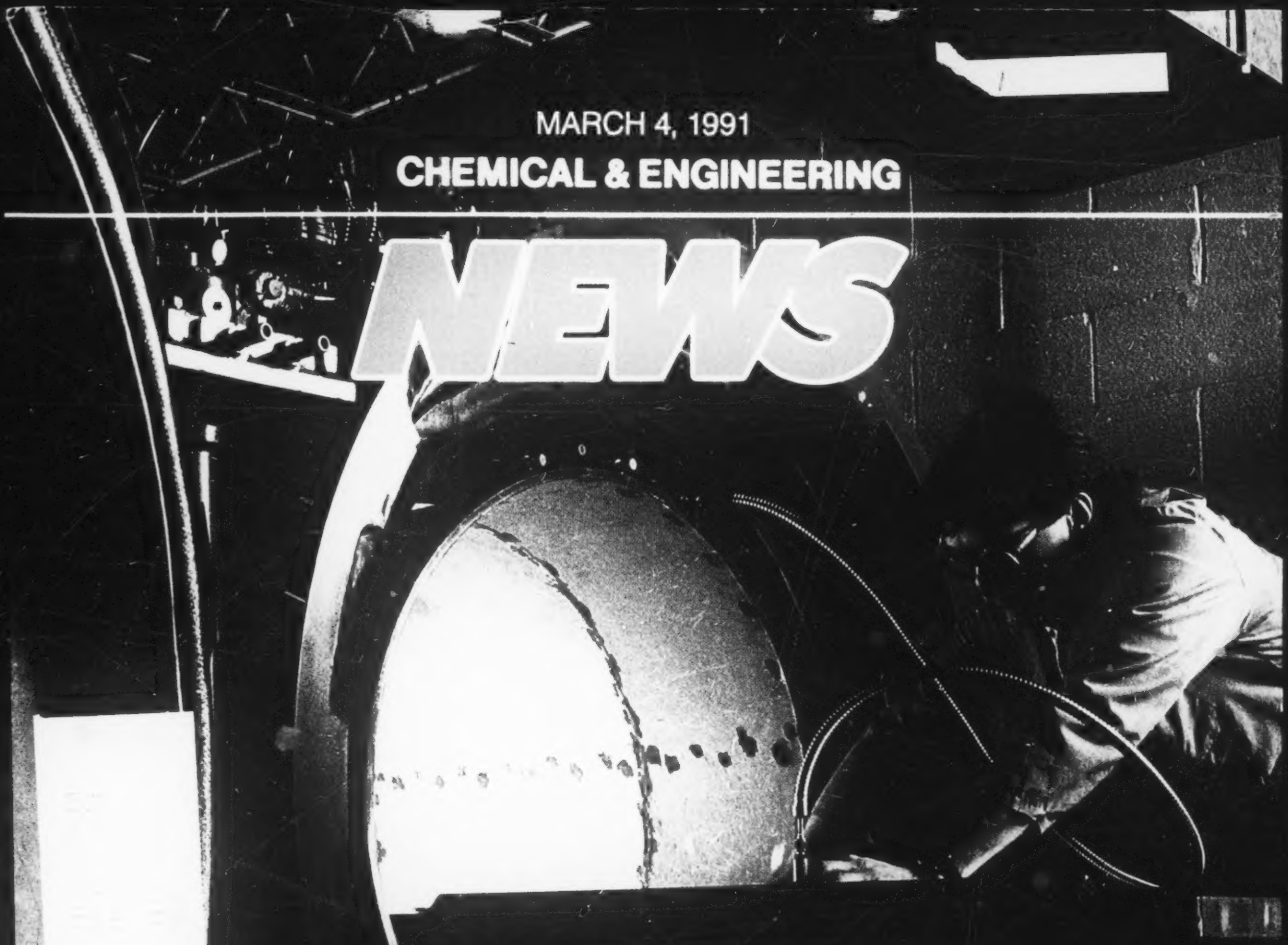
Cytogen, which has applications filed for approval of two mAb cancer imaging agents that deliver radioisotopes to specific tumor sites, is a leader in this area. The company is testing similar design radioisotope-based therapeutic agents in Phase I—soon moving into Phase II—trials, which have yet to be studied for efficacy in ovarian and gastrointestinal cancers.

Cytogen's products employ a proprietary "linker" technology, generally some sort of chelating group attached to the mAb, which binds a radioisotope and delivers it to specific tumor sites. The company has licensed its linker technology to major pharmaceutical companies interested in tying chemotherapeutic agents to mAbs for site-specific delivery.

A mAb development goal is achieving low dose levels when the linker does not interfere with the ability of the antibody to find its target and bind effectively. Because of the specificity and potentially lower doses required, mAb agents may offer an advantage in reducing the side effects common with chemotherapy. For the same reason, mAb agents are expected to be unlike chemotherapy, which targets any rapidly dividing cells in the body and thus can damage healthy cells.

Like other biopharmaceuticals, the regulatory route for mAb products is mostly uncharted and has yet to fall into a pattern. The time it will take for approvals and the eventual success of these and other products is still unknown. As more products are approved, second-generation versions developed, and biopharmaceuticals are established in positions in pharmaceutical markets, companies can expect to face new issues along with continuing debates on patents and orphan drugs. Most industry and outside observers are anticipating that the costs of relatively expensive, yet novel, biotechnology drug products will have impact on markets, competition, and profits, particularly as health care costs and reimbursement issues become even more critical. ☐

MARCH 4, 1991
CHEMICAL & ENGINEERING
NEWS



ADHESIVES

Expanding applications are demanding
higher performance
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CENEAR 69 (9) 1–68
ISSN 0009-2347

CHEMICAL & ENGINEERING
NEWS
MARCH 4, 1991

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- **Chemical, biological arms issues likely to remain on U.S. agenda despite cease-fire in Gulf war.** Page 5
- **Pharmaceutical Manufacturers Association pushes for laws boosting incentives for developing orphan drugs.** Page 5
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Business

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Proposed free trade agreement between the U.S. and Mexico is solidly backed by the chemical industry. **Page 11**

Western drug companies may get a foothold in the Japanese market as the result of organizational restructuring in the country. **Page 13**

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Researchers claim "bond-stretch" isomerism, in which two isomers differ only in length of metal-oxygen bond, may be an artifact. **Page 20**

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Cover: American Cyanamid researcher tests adhesive in high-temperature, high-pressure autoclave at company's structural adhesives manufacturing facility at Havre de Grace, Md.

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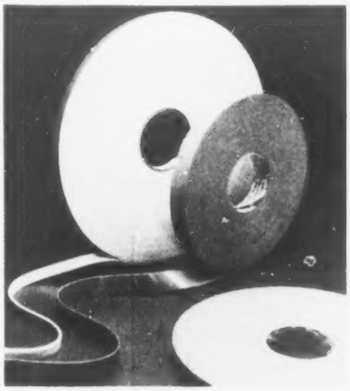

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U.S. adhesives manufacturers are working feverishly to develop adhesives with higher performance characteristics to meet demands of high-tech applications. Page 23

Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
Robert H. Marks, Director, Publications Division

PUBLISHING BOARD: Jean'ne M. Shreeve *(Chairman); Board of Directors Chairman:* Joseph A. Dixon; *President:* S. Allen Heininger; Richard L. Deming; William P. Jencks; Gary J. Long; and Louis D. Quin

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Subscription Rates 1991. Printed editions: nonmembers U.S. 1 yr. $95, 2 yr. $171; outside U.S. 1 yr. $131, 2 yr. $243. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $12. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Beyond uranium

The article "Beyond Uranium" by George Kauffman (C&EN, Nov. 19, 1990, page 18) is a most fascinating and informative document. The names of the researchers read like a litany of patron saints in this esoteric field and should be considered an essential component of any textbook dealing with this subject. Too often, we teach the fundamentals of science without taking time to credit the genius and humanity of those who spend a lifetime unraveling the magnificent mysteries of nature.

This letter was prompted by a small reference on page 22 of the above article to a Michael Cefola, who was a member of the team that isolated the first visible quantity of pure plutonium fluoride back in 1942 at the University of Chicago. Some 35 years ago, I was fortunate enough to do graduate work under professor Cefola at Fordham University. He was a superb teacher as well as a warm, modest person who was most highly respected and loved by his students and colleagues. It took too many years for me to realize just how fortunate I was to have studied under one such as he, inasmuch as his unassuming nature never once alluded to his microanalytical contributions to the historic Manhattan Project.

Peter C. Szap
Department of Chemistry
Georgian Court College

Universities in Hong Kong

With reference to the article "Hong Kong Suffers Brain Drain As It Prepares To Rejoin China" (C&EN, Oct. 22, 1990, page 21), I would like to make the following clarification with regard to the higher education scene in Hong Kong.

Currently, there are six institutions financially supported by the Hong Kong government via the University and Polytechnic Grants Committee as follows: the University of Hong Kong, Chinese University of Hong Kong, the newly established Hong Kong University of Science & Technology, Hong Kong Baptist College, Hong Kong Polytechnic, and City Polytechnic of Hong Kong. They are essentially all supported by government funds and thus are not private universities as described in the article.

Moreover, all six institutions offer undergraduate degree programs and thus the undergraduate training is not, as described, confined to the two polytechnics. As a matter of fact, Hong Kong Polytechnic in the past offered courses only for the award of higher certificates and diplomas with emphasis on the training of skilled technicians. However, they have offered both degree and diploma courses over the past eight years, and emphasis has shifted to offering courses leading to the award of degrees.

Hong Kong University is the oldest university in Hong Kong and stress has been placed on research and postgraduate training. However, research is an important element for any tertiary institution, and all the other institutions also make notable contributions to research and postgraduate training in Hong Kong.

Y. S. Fung
Vice Chairman
Hong Kong Chemical Society

Benefits of pesticides

I wonder if other chemist readers reacted to the review of a book that appeared under the heading "Third World Agricultural Tragedies" (C&EN, Dec. 17, 1990, page 32) as I did. The book and the review seem to fit a pattern of knocking the benefits of science and stressing costs over benefits that recent ACS leaders have blamed, at least in part, on poor science education in American schools. Others would see it as an expression of a back-to-nature bias of an affluent society.

I suppose it's sporting to expose readers of C&EN to some of the negative effects of the use of chemicals, and few deny that there have been negative effects. It does seem a bit incongruous, though, to read such a one-sided attack on the products of the creative activities of ACS members in the ACS news magazine without that magazine's making some effort to present the benefit side of the equation in equally enthusiastic terms.

There are many of us who work in the agrochemical field who feel that what we are doing is extraordinarily worthwhile. The combination of new crop varieties, fertilization, and agrochemicals has prevented the mass starvation that

Correction

- Feb. 25, page 28: The caption for the angiogram photos should read: Angiograms showing blood flow in blocked coronary arteries (right) indicate improvement after treatment (left) with TPA.

Italy's Chemical Industry Looks To Expand Beyond Country's Borders

Although dynamic and growing, industry is highly fragmented, will turn to mergers and joint ventures in drive toward globalization

Patricia L. Layman, C&EN London

The Italian chemical industry is, by the calculations of CEFIC, the European Chemical Industry Council, in a toss-up for third largest chemical industry in Western Europe, vying with the U.K. for that honor (after Germany and France).

Historically, cynical observers have asked, "Is it for real?" And yet, the joke has only been made by the chemical industries in other countries, both in and outside Western Europe. Despite fragmentation and lack of renown outside Italy, the industry remains dynamic and growing—even though this year probably will see a slight slowdown in growth from 1989 and 1990.

Sales of the Italian chemical industry in 1990 were roughly $54.5 billion, an increase of 1.6% in real terms over those of 1989, accounted for by more than 1200 producers and marketers of chemicals, plastics, specialties, pharmaceuticals, and a variety of allied products. However, much like the comparable industries of other Western European countries, its production and sales are dominated by only a few giants, with several tiers following them.

At the top of the list has been Enimont, the ill-starred joint venture between ENI, the Italian state-owned energy company, and privately held Montedison. The venture was put together in January 1989; after floundering about with no cohesive strategy—or no cohesive political will to put a strategy into effect—the venture was wound up in January 1991, after two years of what essentially was wasted time. Montedison's share was sold to ENI, which now runs the operations under the name EniChem.

During the life of the venture, Enimont chalked up sales of $13.6 billion in 1989 and probably even higher in 1990, although no figures have been released yet. Whatever the sales are, however, they will dwarf those of the next largest Italian chemical company, Montedison, in turn renamed Montecatini at the beginning of this year. Montedison's sales in 1989 were $5.19 billion; even lumping in sales of its subsidiary, Himont, that would bring the 1989 total to only $5.88 billion. The third largest is Italian holding company Snia BDP with interests in synthetic fibers and explosives, among other things, and 1989 sales of $2.17 billion.

Below Snia is another tier of companies made up of the Italian subsidiaries of multinationals, such as Dow Chemical, Solvay, Procter & Gamble, and 3M. Not until the pharmaceutical company Bracco Industria Chimica, with sales of $441 million in 1989, does another Italian-headquartered chemical producer appear on the roster.

The host of small to medium-sized companies making up the chemical industry in Italy has, in fact, led Roberto Sestini, vice president of the Italian chemical manufacturers' federation, Federchimica, to refer to its "pulverization."

These companies account for a significant proportion of the activity in the specialized sectors of the Italian chemical industry, which last year was 32% of total production. Fine chemicals accounted for 26%, and basic chemicals the remaining 42%.

The other side of the coin, however, shows that in 1990, specialty chemicals accounted for 43% of the Italian chemical trade deficit, fine chemicals 20%, and basic chemicals 37%. In 1987, those figures were nearly reversed: Specialties accounted for 39% of the chemical trade deficit, fine chemicals 18%, and basic chemicals 43%. The trend underlines the increasing importance of specialty, higher value-added chemicals to the Italian industry—but also the weakness of smaller companies, with their more limited financing, marketing, and production facilities, to compete effectively in an international arena.

However, Sestini believes the fragmentation of the industry is both a strength and a weakness.

The president of Italian industrial gases producer Societa Italiana Acetilene e Derivati (SIAD), in Bergamo, Sestini cites his own industrial gas industry as an example. "Small companies can survive very well. They

Sestini: fragmentation is both a strength and a weakness are working in a small area, but they can have low costs." However, the disadvantage comes when an industry is turning to new technology and the smaller companies have limited or no access to new markets.

Over the next five years, he suggests, smaller companies will agglomerate, or be acquired. There will be less and less room in the marketplace for the small company that, by taking no positive action, remains small.

Smaller companies might merge—or they might form alliances with larger operations, Sestini adds. SIAD provides a case in point. In 1989, it formed a venture with Union Carbide and EniChem to work with molecular sieves for oxygen separation and membranes for nitrogen separation. Union Carbide provides the technology on molecular sieves, and EniChem, production capacity; the Italian company contributes its knowledge of domestic markets and marketing.

Ventures to reinforce work in research and development can also lead to joint ventures and alliances, says Adriano Teso, chairman of coatings company IVM SpA., based in Milan. IVM has specialized in the wood finishes sector. "It is necessary to concentrate, to have critical mass for production of resins, for R&D, and so on," says Teso, whose company, or its forerunners, have focused on wood varnishes and specialty polymer coatings since after World War II.

"Critical mass is very important to get the right developments. Even ICI, for example, is only in four or five coatings sectors, as is PPG. They are not in all of them. Because we started little, to have good results, we have had to concentrate on one sector," Teso adds.

Venturini: big changes in next decade

Teso argues that fragmentation in the industries his company serves has, in turn, provided benefits to IVM and other Italian chemical producers. "As an Italian company, we've had a little advantage: The Italian furniture industry is very developed, with production systems very different and very complex. To be in this market, to work in this market, we had to produce a lot of systems. The market forced us to become very competitive."

In Western Europe, points out SIAD's Sestini, "there is only one country—Italy—where small or medium-sized industries are still private. In the other countries, the multinational companies are present," as strong manufacturing sources rather than merely as commercial sellers of goods. "It is very difficult for an Italian company to buy a company outside Italy. It is much easier for the multinational to buy the Italian private company."

Italian chemical industry growth will slow this year

$ Billions	1991[a]	1990[b]	% change[b] 1990-91	% change[b] 1989-90
Sales	$58.850	$54.513	1.2%	1.6%
Imports	24.779	23.186	2.0	5.0
Exports	14.867	13.894	2.0	3.0
Net consumption	68.761	62.920	1.2	2.6

Note: $1.00 = 1130 lire. **a** Estimated. **b** Corrected for inflation.
Source: Federchimica

With that potential threat concentrating the minds of the Italian industry, companies are looking at how to grow and expand beyond the country's borders, but the process is difficult and slow for small companies, compared with the industrial giants, requiring patience and persistence. SIAD, Sestini points out, is "now looking outside Italy, also." It could have tried expanding on the strength of the venture with Union Carbide and EniChem—everyone knows Union Carbide, he points out. However, it opted instead to tackle the challenge alone: "We decided about two years ago to go outside Italy with SIAD. We opened a SIAD branch company in Austria, and this year will start a joint venture in Yugoslavia." And it has a commercial office in Bucharest to keep tabs on opportunities opening in Eastern Europe.

It is a limited and specific goal, says Sestini: "We want to be 'global in Europe.' "

To accomplish that kind of goal, it is increasingly clear that small to medium-sized chemical companies in Italy will turn to joint ventures and alliances. That's the same route, ironically, that the Italian giants have taken, as they drive toward globalization.

EniChem, for example, has been particularly active over the past four or five years in setting up joint ventures both in Western Europe and, more important, in Eastern Europe and the Far East. And Montecatini officials have indicated that, rather than grand acquisitions, it will look for alliances and joint ventures to help it grow through the coming decade, strengthening its geographical and product coverage.

As Guido Venturini, director general of Federchimica, sees it, the next decade will be particularly important for the Italian chemical industry as it grows and copes with a revolution in how the industry does business. There will be new technologies—biotechnology, new materials, new R&D projects, and so on; continued production automatization; and new marketing technologies, as well as a growing environmental imperative.

"It is a must," he says. "The Italian chemical industry of 10 years from now will be different than today. It is not only a question of economics, capital, and so on—the sector itself will be changing. And because of the dynamic approach to capture survival, such actions as takeovers, or creating new company groups, will be just one of the angles." ☐

U.S. chemical industry backs free trade with Mexico

Earl V. Anderson,
C&EN Northeast News Bureau

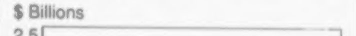
There's no shortage of opposition to the proposed free trade agreement between the U.S. and Mexico, from many in Congress, labor, and agriculture. The chemical industry, however, is solidly behind the idea.

Testifying at hearings held recently by the House Ways & Means Committee's trade subcommittee, Dexter F. Baker, chairman and chief executive officer of Air Products & Chemicals, said the chemical industry supports the idea of negotiating a free trade agreement with Mexico. And, he adds, it also believes that if Canada participates in the trade talks as planned, the negotiations could lay the foundation for a true North America Free Trade Agreement. Until recently, such an agreement—or NAFTA as it has been called—has been little more than a dream.

Baker testified on behalf of the Chemical Manufacturers Association, which represents 90% of the U.S. capacity for making basic industrial chemicals. Although he is also head of the Office of the Chemical Industry Trade Adviser, a group of several chemical industry trade associations, including CMA, he did not wear that hat when he testified.

This does not mean that the U.S. chemical industry is divided on the Mexico free trade issue, says Baker. It was just a matter of timing. Other members of OCITA simply did not hold their meetings in time to endorse the policy that he outlined before the trade subcommittee. But he expects other OCITA members to climb aboard, as they have on most other trade issues.

U.S. has huge chemical trade surplus with Mexico



Source: Bureau of the Census

Certainly the chemical industry has reason to give the proposed free trade talks a high priority. Although U.S. chemical trade with Mexico pales beside trade with Canada, Japan, or the European Community, it is nevertheless large—and growing. U.S. chemical exports to Mexico last year were valued at $2.3 billion, about 6% of the total. But that value is virtually double what it was in 1986. Chemical imports from Mexico, however, are small by comparison. Mexico shipped the U.S. $665 million worth of chemicals last year. That's only 3% of total U.S. chemical imports, but it represents an 80% increase over that in 1986.

Baker is encouraged by recent developments in Mexico. He gives high marks to the fact that Mexico even wants a bilateral trade agreement with the U.S. Former Mexican President Miguel De La Madrid Hurtado started many economic reforms in his country, reforms that the current President, Carlos Salinas De Gortari, is continuing.

Salinas has recently liberalized laws governing technology transfer, investments, and imports. As a relatively new member of the General Agreement on Tariffs & Trade (GATT), Mexico has "bound" its tariff rates far below those of other developing countries.

As a result, Baker believes that chemical trade between the two countries can flourish under a free trade agreement. However, the U.S. chemical industry has its own ideas about what should come out of the trade negotiations. Its general objectives are to ensure market access in Mexico for U.S. chemical producers, the right to freely invest in Mexico, and the opportunity to harmonize Mexican and U.S. "trade remedy" laws. These are the laws, such as antidumping laws, that provide relief to an industry or company hurt by imports.

Baker: encouraged by developments

According to Baker, the negotiations should tackle some of the current Mexican practices that he says distort the U.S. chemical trade with that country. For instance, he wants to see Mexico eliminate its dual-pricing procedures, by which, among other things, Pemex gives domestic customers a lower price than customers in the export market. Pemex is the state-owned petroleum company (Petroleos Mexicanos) that by law is the sole producer of primary petrochemicals in Mexico.

Mexico already has taken some giant steps to liberalize foreign investment laws in the petrochemical sector. Now, only 86 chemicals require some form of Mexican government participation, while only 20 primary petrochemicals are completely reserved for Pemex (Mexico eliminated many products from its list of "primary" petrochemicals).

That's progress, but Baker wants to see Mexican foreign investment rules eased further for petrochemicals. The negotiations, he says, should focus on the trade impact of policies that reserve portions of some industries for the government.

Baker also thinks that negotiators should try to harmonize the two countries' trade remedy laws. At the very least, he says, these laws should

Most U.S. chemical trade with Mexico is in basic chemicals

	1990			1989			1988		
$ Millions	Exports	Imports	Trade balance	Exports	Imports	Trade balance	Exports	Imports	Trade balance
Organics	$ 603	$157	$ 446	$ 691	$158	$ 533	$ 660	$114	$ 546
Inorganics	224	236	−12	206	204	2	169	194	−25
Dyeing, tanning & coloring materials	99	39	60	69	33	36	51	40	11
Medicinals & pharmaceuticals	106	15	91	74	17	57	74	23	51
Essential oils, perfumes, toiletries, polishing & cleansing materials	131	44	87	88	39	49	39	40	−1
Fertilizers	44	15	29	57	10	47	28	3	25
Plastics in primary form	537	31	506	545	35	510	629	158	471
Plastics in nonprimary form	326	76	250	284	59	225	a	a	a
Miscellaneous	254	52	202	210	28	182	180	23	157
TOTAL	**$2325**	**$665**	**$1660**	**$2225**	**$582**	**$1643**	**$1830**	**$595**	**$1235**

Note: Totals may not add due to rounding. a Prior to 1989 the Bureau of the Census did not use the classification "plastics in nonprimary form." **Source:** Bureau of the Census

provide for national treatment and guarantee due process for all parties in both the U.S. and Mexico.

Any free trade agreement between the U.S. and Mexico also should contain a workable dispute-settlement mechanism, Baker told the Congressional subcommittee. He suggests that it be modeled after the dispute-settlement procedures contained in the Canada-U.S. free trade agreement.

But for the U.S. chemical industry, one of the major goals of the trade talks with Mexico, as it has been in the stalled Uruguay round of multilateral trade talks in Geneva, is "market access." By definition, market access has come to encompass both tariffs and nontariff barriers.

What the U.S. chemical industry wants in a trade agreement with Mexico is "market access without unreasonable barriers," says Baker. The agreement should provide each country with improved and equivalent access to the other country's markets, including petrochemicals. To achieve this, both tariffs and nontariff barriers must be progressively eliminated, he says. Baker stresses that tariffs should be reduced and eliminated in stages over a five or 10-year period. Tariffs on some products, he adds, could be eliminated immediately through an acceleration process if producers in both countries agree. This is what has already happened for many chemicals under the Canada-U.S. free trade agreement.

But Baker hopes that negotiators can avoid one pitfall contained in the Canada-U.S. agreement. Under that pact, any producer can block a proposal to accelerate a tariff cut, regardless of how small an interest that producer has in the product. Baker believes that a company should at least be competitive in its own market before it can enjoy the right to block a proposed acceleration in tariff cuts that the major producers favor.

But nontariff barriers, as well as tariffs, also are on the chemical industry's list of concerns. One in particular is a rule of origin. The industry wants negotiators to come up with a rule of origin by which most of the benefits of a Mexico-U.S. agreement would go to the nationals of those countries. The idea is to prevent a third party from, say, shipping its product into Mexico, doing a token amount of work on the product, then shipping it into the U.S. with the benefit of low—or no—tariffs.

Baker says a trade pact should require that any product imported into Mexico or the U.S. be "substantially" transformed before it could be considered as a product of that country and eligible to be exported to the other under preferential tariff rates. There are some problems with the rule of origin written into the Canada-U.S. agreement, Baker notes, and the Mexican and U.S. negotiators should take that experience into account.

Domestic technical standards are another possible problem that the chemical industry wants negotiators to consider. These, says Baker, could hinder free trade by unfairly excluding products of foreign countries. To make sure that technical standards do not become a significant trade barrier, Baker says there should be some mechanism established to monitor and harmonize U.S. and Mexican standards.

And, although Mexico has come a long way in improving its laws protecting intellectual property, the U.S. chemical industry believes more can be done. Mexican law, for instance, does not extend patent protection to fine chemicals or pharmaceuticals.

Opponents of the proposed Mexico-U.S. trade pact, including many in Congress, fear that some U.S. companies will move their plants to Mexico to avoid high labor costs, or the high costs of complying with U.S. environmental regulations, or both. Baker assured the committee that this would not be the case in the chemical industry.

First, the industry is capital-intensive; labor costs are not a major factor. And environmental issues won't be a factor, either. Mexico already is stiffening its environmental protection laws. And, points out Baker, U.S. chemical companies build their foreign plants to meet the most stringent environmental standards. □

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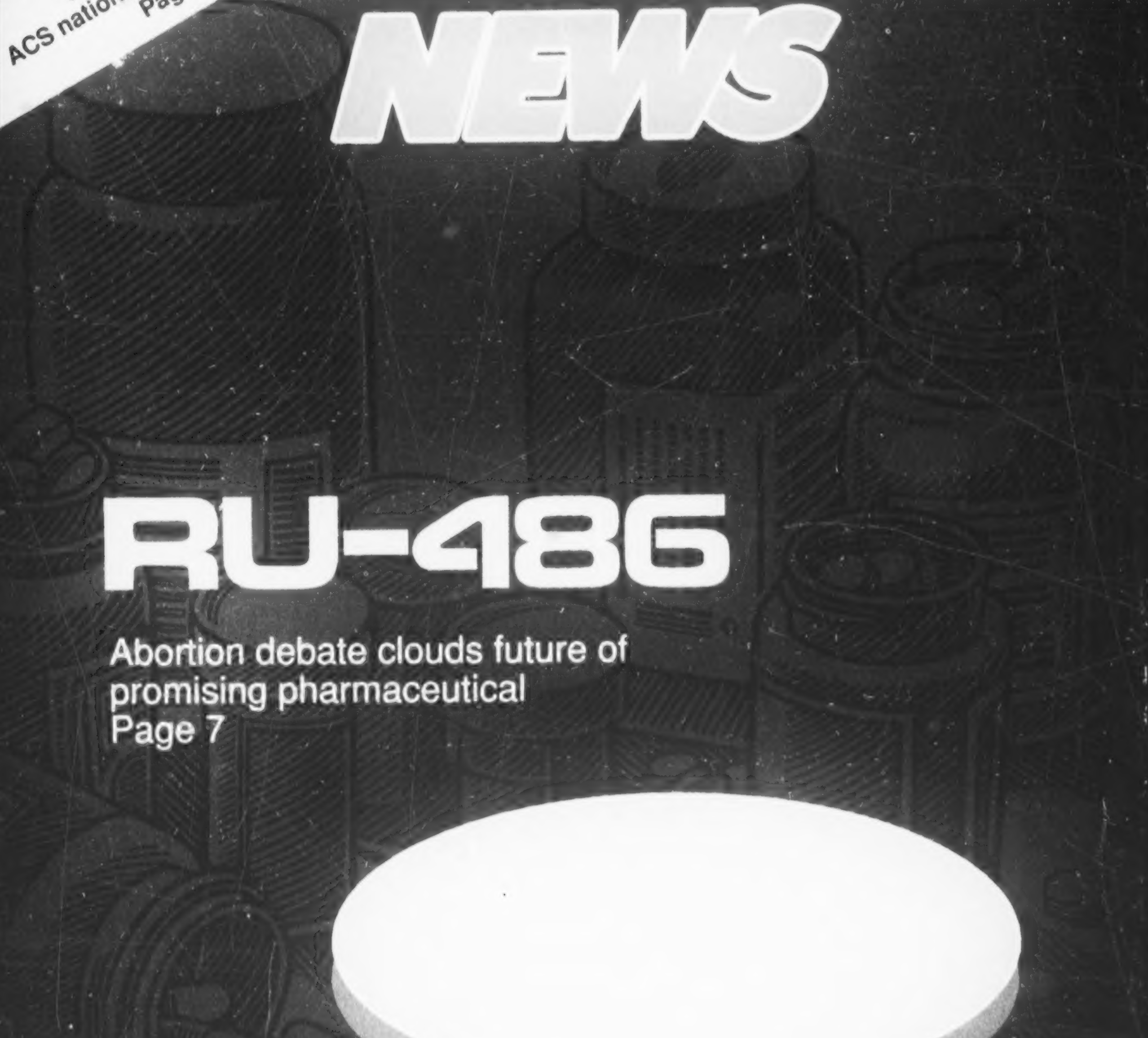

RU-486

Abortion debate clouds future of
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- **Scientists and environmental groups express concern over environmental devastation created during recent Persian Gulf War.** Page 5
- **Controversy erupts over metallization of hydrogen, with two groups of scientists questioning validity of data.** Page 5
- **Massive international study of blood-clot dissolving drugs could have major impact on sales of highly competitive thrombolytic agents.** Page 6
- **Witnesses at hearing in Houston back concept of OSHA's proposed plant safety rules for petrochemical industry, but raise objections on implementation.** Page 6

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Worldwide ethylene capacity expansion will cut U.S. exports of plastics and intermediates, slow production growth. Page 19

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New FDA commissioner comes to agency with tough agenda aiming to increase its inspections and enforcement. Page 25

Bush's energy plan has opened a debate that has free marketeers facing off against an energy conservation coalition. Page 22

Science/Technology

Expanded aid policy by Netherlands' government will assist nations of Central, Eastern Europe in managing environment. Page 26

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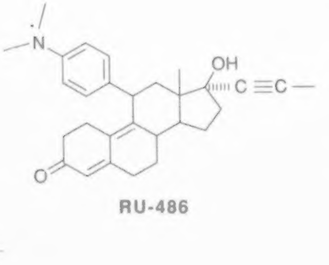

RU-486

News Focus

RU-486, a progesterone antagonist developed in France and used to terminate pregnancy, is potential anticancer and anti-Cushing's agent, but abortion controversy hinders U.S. research on it. Page 7

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1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
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Subscription Rates 1991. Printed editions: nonmembers U.S. 1 yr. $95, 2 yr. $171; outside U.S. 1 yr. $131, 2 yr. $243. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel. (03) 272-7211. Single copies: Current $12. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

CHEMICAL SAFETY

Explosions from organic azides, peroxides

I wish to report two incidents that may be of interest. In the first, a 25-g preparation of 1,4-diazido-2-butene exploded during purification by high-vacuum short-path distillation. The distillation temperature had reached approximately 70 °C in the pot when the explosion occurred. At the time of the explosion, one employee had removed the shielding to prepare to shut down the operation. This employee received facial burns and lacerations, but safety glasses prevented permanent eye injury. A second employee across the room received a minor laceration from flying glass. The force of the explosion destroyed the distillation apparatus and nearby glassware, spilling methanol, oil, and about 50 mL of mercury.

Organic azides are known to exhibit dangerous instability, especially those containing unsaturated carbon-carbon bonds and more than one azido group. Heat, shock, and traces of strong acids or metallic salts may trigger explosive decomposition. These compounds must be handled with extreme caution on a small scale, while ensuring the protection of employees and surrounding equipment in the event of an explosion. It should be noted that this material had been distilled in this fashion without incident several times previously, illustrating the unpredictable nature of these substances.

The second incident involved a 500-mL bottle of peracetic acid packaged with what appeared to be paper absorbent in a metal shipping container. The container had been placed on its side, allowing liquid to leak through the bottle's vented cap (peracetic acid bottles are vented to allow release of the pressure that builds up from the normal slow decomposition of the material). The spilled liquid reacted exothermically with the absorbent, heating the metal can until it became quite hot to the touch. Luckily, the heat generated did not trigger any further reaction. Heating peracetic acid above 65 °C may cause self-accelerating decomposition, and temperatures above 110 °C will cause violent explosion. This incident emphasizes the importance of ensuring compatibility between packaging materials and reactive chemicals such as peroxides.

Bruce I. Tobias
Chemical Safety Officer
Environmental Control & Research Program, Frederick Cancer Research & Development Center
Frederick, Md.

Editor's note: Numerous references to the instability of organic azides will be found in the literature, including the fourth edition of "Bretherick's Handbook of Reactive Chemical Hazards" [Butterworth-Heinemann, Stoneham, Mass. (1990)].

Stereochemical puzzle

I would like to draw attention toward the excellent comment by Ernest Eliel and Samuel Wilen on the term homochirality (C&EN, Sept. 10, 1990, page 2). I quite agree with my distinguished colleagues, since homochiral doesn't mean strictly enantiomerically pure.

This is another example of the increasing stereochemical puzzle, where there is an almost babel-like confusion. Terms like stereoselective, stereospecific, chemo- or regioselective, among others, are often defined in different ways—and, unfortunately, are not completely unambiguous. Another interesting dichotomy emerges from the dynamic stereochemistry. The widely used term of asymmetric synthesis was first introduced by Marckwald [*Ber.*, **37**, 1368 (1904)], as the process of forming an optically active compound through the reaction of an achiral substrate with a (homo)chiral reagent. A broader definition can be found in "Asymmetric Organic Reactions" by James D. Morrison and Harry S. Mosher [Prentice-Hall, Englewood Cliffs, N.J. (1971)]. Curiously, the term asymmetric induction was coined later [McKenzie and Ritchie, *Biochem. Z.*, **237**, 1 (1931)] to describe the chirality induced in the symmetrical portion of a molecule by an asymmetric center in a different portion of the same molecule, when the latter reacts with an achiral reagent.

Obviously, both concepts are not strictly synonymous, although both are currently misused as equivalents. The term chiral synthesis, which extends and simplifies these concepts, is gaining in-

AIDS RESEARCH:
More funds, coherent strategy needed

The National Institutes of Health has responded with unprecedented speed to the crisis of the acquired immune deficiency syndrome epidemic. "Never has so much been learned so quickly about any disease," William H. Danforth, chancellor of Washington University, St. Louis, told the House Government Operations Subcommittee on Human Resources & Intergovernmental Relations last week.

But, Danforth also stressed, as the AIDS research program stands on the verge of its second decade, it needs more funds—perhaps as much as 25% more than the $805 million it is getting this year. And it needs a coherent research strategy.

The hearings were called by the subcommittee chairman, Rep. Ted Weiss (D.-N.Y.), to review the results of a yearlong study of NIH's AIDS research program carried out by a panel chaired by Danforth and issued last week. The panel was organized by the Institute of Medicine, an affiliate of the National Academy of Sciences, at NIH's request.

After much debate, Danforth said, the panel decided that the current administrative structure—an "institute without walls"—that has evolved for handling AIDS research is the best mechanism possible. The panel does not recommend consolidating AIDS research under a single NIH institute, "because no one institute is broad enough to provide all of the separate strands that must come together for success in dealing with HIV [human immunodeficiency virus] and AIDS."

However, that doesn't mean the study found no need for change. Panel member Melvin M. Grumbach, Edward B. Shaw professor of pediatrics at the University of California, San Francisco, said that "without a decisive breakthrough on the immediate research horizon, there is a compelling need to strengthen and institutionalize the organizational and administrative approaches for managing AIDS research as a long-term program."

Currently, Grumbach told the subcommittee, NIH's "planning for the AIDS program is linked almost entirely to the budget process; that is, it is based on anticipated resources and not on well-defined program goals and potential scientific opportunity." The past 10 years have seen funding for AIDS research increase from 0.1% of NIH's total budget to just under 10% in 1990. However, that rapid growth seems to be over, with AIDS funding holding at just under 10% in fiscal 1991 and 1992.

The time has come, Grumbach said, for NIH "to dig in for the long haul." To the IOM panel, that means it's time for NIH to develop a five-year plan to identify AIDS-related research needs and opportunities, determine priorities and program balance, identify research fields that need to be developed, define the resources needed to carry out the plan, and monitor its progress.

Funding for AIDS levels off at 10% of NIH budget

$ Millions	NIH		AIDS % of total
	AIDS	Total	
1982	$ 3.4	$3643.5	0.1%
1983	21.7	4013.1	0.5
1984	44.1	4493.6	1.0
1985	63.7	5121.6	1.2
1986	134.7	5198.0	2.6
1987	260.9	6175.0	4.2
1988	473.3	6610.4	7.2
1989	602.3	7144.8	8.4
1990	740.5	7581.5	9.8
1991[a]	804.6	8276.7	9.7
1992[b]	851.2	8774.9	9.7

a Estimate. b NIH fiscal 1992 budget request. **Source:** Institute of Medicine report "The AIDS Research Program of the National Institutes of Health"

To do this effectively, the study says that NIH needs to expand its AIDS Program Advisory Committee to include a broader array of AIDS-related research expertise, and needs to give that group more responsibility for broad policy advice and program surveillance. The NIH associate director for AIDS research needs additional planning and evaluation staff support and more senior scientists.

And echoing a recommendation by other review groups, the panel says the NIH director should have an annual discretionary fund of $20 million, and the authority to transfer up to 1% of each NIH appropriation account to respond rapidly to unanticipated research directions or new critical health problems. The committee also made specific recommendations on various areas of AIDS research, including vaccines, epidemiology, behavioral research, preclinical drug development, and clinical trials.

Overall, Weiss found the IOM report to be "an extremely constructive guide to improving the NIH AIDS research program," and said "it should be taken seriously by the NIH leadership and full consideration should be given to its recommendations."

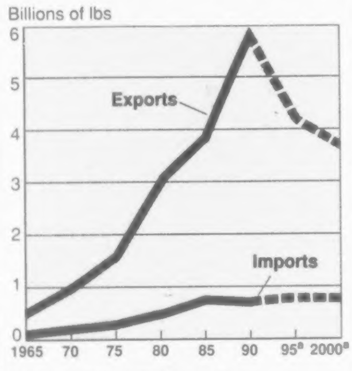
Apparently, that is already happening. Anthony S. Fauci, NIH associate director for AIDS research, told Weiss that the IOM committee "made a number of constructive suggestions. Many of the recommended adjustments to the program outlined in the IOM report are already under way and others are under review for future action."

Janice Long

Global plant expansions will dampen U.S. exports

Additions to global steam cracker capacity will reduce exports of plastics and intermediates and will slow U.S. production growth during this decade. The slackening growth and larger capacity will boost competition among producers worldwide, resulting in a slide in profit margins. Producers of polyethylenes, polypropylene, and polyesters and intermediates, such as *p*-xylene, will be hit the hardest, pointed out several speakers at the Chemical Management & Resources Association meeting in San Antonio, Tex., late last month. The theme of the winter meeting was growth opportunities in a changing environment.

After surge, propylene derivative exports will slump



a Forecast. **Source:** Shell Chemical

If expansions of steam crackers are completed on schedule, total capacity will grow faster than global demand for end products using the olefins and aromatics from the crackers, resulting in pressure on selling prices and profitability. Lower profit margins could lead to shutdown of some of the old and costly-to-operate plants, offsetting the new capacity additions.

With a significant overcapacity for making the basic large-volume petrochemicals, producers will be required to adapt quickly to changing business conditions if they are to stay profitable.

The keys to survival in today's environment differ from what they were 10 years ago, says Lynn T. Bourdon III, manager of feedstocks supply at Dow Chemical. Successful ethylene producers must have three main production characteristics: First is complete coproduct integration to gain the added value of the coproducts; second is wide flexibility in using many different feedstocks, in having the facilities to deliver different feedstocks from various sources, and in accommodating the output swings that result from changes in the feedstocks; and third is having a global orientation, necessary as the U.S. imports larger quantities of hydrocarbons for all uses.

Global ethylene demand during the early 1990s forecast to grow 3.9 to 4.6% annually, says Samuel M. Weinberger, a business planner at Exxon Chemical. The recent war in the Persian Gulf could reduce growth rates to between 3.5 and 4.2%. Nevertheless, Weinberger says announced ethylene capacity expansions will average 5.5% per year between 1990 and 1995. And of the announced expansions, about half will be in the developed regions of North America, Western Europe, and Japan. Growth in demand, however, is forecast to be almost 60% in the developing regions of the world, leaving 40% of the increased demand to areas where capacity will grow 50%.

Global ethylene capacity to grow 35% through 1995

Thousands of metric tons	Capacity 1989	Capacity 1995	Steam crackers announced for 1990
U.S.	17.6	22.2	5
Canada	2.5	3.0	1
Latin America	3.0	4.4	3
Western Europe	15.7	19.7	5
Eastern Europe	7.1	7.4	6
Middle East/Africa	3.5	5.8	6
Japan	5.6	7.1	3
China	1.6	2.7	4
Other Asia/Pacific	2.7	8.0	17
WORLD TOTAL	**59.3**	**80.3**	**50**

Source: Exxon Chemical

Production growth of ethylene and its derivatives will be high in China and other Asia/Pacific countries, excluding Japan. These countries won't need large imports of petrochemicals from other areas of the world. As a result, the difference between exports of ethylene derivatives and imports in the U.S. will shrink from about 2.4 billion lb of ethylene equivalents in 1990 to less than 1 billion lb in 2000, Weinberger forecasts.

Similarly, U.S. trade in propylene derivatives will decline as global steam cracker capacity expands, according to Merritt Marbach, senior staff economic specialist at Shell Chemical. Exports of derivatives required about 6 billion lb of propylene last year; exports of propylene amounted to 500 million lb. Imports of both derivatives and propylene totaled about 1.2 billion lb in 1990. About 25% of the net trade in propylene is polypropylene, and another 15% is acrylonitrile. By the year 2000, propylene equivalents in derivatives exported will be down to about 3.7 billion lb.

This decade will produce no important supply problems for propylene, says Marbach. Chemical demand will grow at about the rate of the gross national product, and this can be met from steam cracker expansions. Thus, chemical demand for propylene produced in refineries will remain flat. However, new gasoline formulations to meet requirements of the Clean Air Act could increase demand for propylene to make alkylate.

Reformulated gasolines and demand variations for polyester fiber could affect *p*-xylene demand and supply in various ways, says James N. Raymaker, product manager for fiber intermediates at Chevron Chemical. He forecasts that, on balance, there will be a smaller merchant market for *p*-xylene, even with increased capacity. Pressures on profitability will come from tighter feedstock availability, regionalized markets causing increased freight costs, and added investment to meet higher purity specifications. With increased consumption of polyester fibers, global demand for *p*-xylene could double to 14 million metric tons by 2000.

Bruce Greek

MARCH 18, 1991

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Volume 69, Number 11
CENEAR 69 (11) 1-84
ISSN 0009-2347

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News of the Week

- **Stanford University officials faced Congressional fire during hearings into assertions that the college has been overcharging for indirect research costs. Page 4**
- **Congress readies for hearings on support for U.S. basic research, focusing on report from Office of Technology Assessment. Page 5**
- **By happenstance, EPA discovers that quicklime destroys PCBs, apparently leaving only harmless by-products. Page 5**
- **Ethylene oxide unit at Union Carbide's Seadrift plant in Texas explodes, killing one and injuring 19. Page 6**

Cover: Photo by C&EN's James Krieger

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Business

Growth in world production of synthetic fibers halts after nearly 10 years of increases; Crompton & Knowles' Alcorn receives CDA award. **Page 9**

Government

Concerned about Great Lakes' slow ecological progress, coalition of environmental groups pushes for zero discharge of chemical pollutants into lakes; tritium is key factor in plans to reconfigure nuclear weapons complex to make it smaller, safer, and cheaper to run; EPA commits to a strategy of halting pollution at source, saying it is most effective, less costly way to reduce risks. **Page 12**

Science/Technology

Chemical engineer, readying for possible role on space shuttle, sees opportunities in space R&D; California chemists develop microelectrode with rapid response capabilities for in-vivo neurochemical research; corporate sponsors sought for student science and engineering fair. **Page 16**

Books

"**Hazardous Waste from Small Quantity Generators**" offers valid points and policy alternatives, but leaves some questions unanswered. **Page 64**

ACS News

Few mass terminations of chemists reported recently; still, there have been a substantial number of unverified firings, and older chemists continue to bear the brunt of these. **Page 67**

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THE PITTSBURGH
CONFERENCE
AND EXPOSIT

Instrumentation '91

42nd edition of the Pittsburgh Conference & Exposition, held this year in Chicago, was organization's largest, with more than 950 exhibitors. Page 20

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1155—16th St., N.W., Washington, D.C. 20036

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Published by
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(202) 872-4600; TDD (202) 872-4432
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Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Supporting data

Sheila Tobias' book, "They're Not Dumb, They're Different: Stalking the Second Tier," which was capably and knowledgeably reviewed by George Bodner (C&EN, Oct. 15, 1990, page 69), is based on a small number of case studies that might arguably be called contrived. A skeptical reader might seriously question the generality of her conclusions based on such a limited data set.

However, support for the book's inferences is found in a report describing a comprehensive longitudinal study of several hundred students carried out at the University of Michigan and published in July 1989. Entitled "An Analysis of Factors Affecting Choices of Majors in Science, Mathematics, and Engineering at the University of Michigan," the brief but comprehensive report is available from the Center for the Education of Women at that university. The conclusions of that study map remarkably consistently on those of the Tobias work.

Robert L. Lichter
Executive Director
Camille and Henry Dreyfus Foundation
New York City

Polymer science education

"Akron Burnishes New Image As Polymer Science Capital" (C&EN, Dec. 24, 1990, page 20) is a case study of how northeast Ohio's economy was revived by a devoted state government, local industries, and premier scientist-educators under Frank N. Kelley's expert directions. We at the University of Lowell Polymer Science Program proudly have alumni from the University of Akron (Sam Sawan) as well as from Case Western Reserve University (Sukant Tripathy). Having spent six years myself at the University of Akron from 1982 to 1988, I had firsthand experience of the exciting changes. I am sure we will continue to hear much exciting news from Akron and Case Western Reserve universities.

I would like to point out, however, that the University of Lowell boasts the oldest accredited B.S. program in plastics engineering in the nation. Since its introduction in 1954 (long before the foundation of the macromolecular science department at Case Western), more than 1200 students have graduated in plastics engineering. Enrollment has averaged 55 for the past 10 years. The chemistry and the plastics engineering departments also have a very successful joint polymer science/plastics engineering graduate program with more than 70 students, visiting scholars, and postdoctoral researchers. To indicate the size of our program, 13 Ph.D. degrees in polymer science/plastics engineering, 20 M.S. degrees in plastics engineering, three M.S. degrees in chemistry (polymer science), and 34 B.S. degrees in plastics engineering were awarded in 1989.

Rudolf Faust
Polymer Group Coordinator
University of Lowell, Mass.

Laboratory safety handbook

Jay Young's review of our book "Laboratory Health and Safety Handbook" (C&EN, Jan. 14, page 26) raises some valid points. It also reflects his personal bias as an author of a competitive work, as well as his limited knowledge in the field of industrial hygiene.

For example, Young's criticism of the omission of ASHRAE 110 as a hood performance test overlooks the fact that this test is neither intended for use in field performance validation, nor is it practical for such use. The hood performance evaluation techniques described in our book are not unreliable, and can actually be used by laboratory personnel (as opposed to the ASHRAE test).

Young criticizes the tone of the book as too conservative. This is a comment often made by chemists about health and safety advice, reflecting the presumption that laboratory workers are either smart enough to protect themselves or are immune to hazards. Unfortunate-

Corrections

- March 4, page 24: Jeff Back is business manager of adhesives and coatings at Kline & Co., not business manager of adhesives, sealants, and coatings for Findtech, Kline's business brokering subsidiary.
- March 11, page 69: In the listing of technical papers for the Atlanta spring national meeting, the Division of Geochemistry paper No. 21 should read "Comparative Biogeochemistry of Three Alkaline, Saline Lakes. **L. G. Miller,** R. S. Oremland, C. W. Culbertson. Paper No. 42 should read "Solid-State ^{13}C NMR and Carbon Isotope Studies of the Coupling of Primary and Secondary Production in a Florida Estuary. **W. T. Cooper,** Y. He, J. Chanton.

Growth in Fiber Output Halts after Nearly 10 Years of Increases

Although down a bit, U.S. still leads in worldwide fiber output with Western Europe the runner-up; only Asian nations record increased production

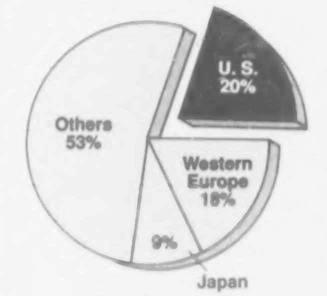
After nearly a decade of growth, world production of synthetic fibers stopped growing last year. That was the analysis, earlier this month, of Dutch chemicals and fibers maker Akzo, whose fibers and polymers division is one of the major global producers in the business.

Global fiber output totaled about 18.9 million metric tons last year, compared with about 19.0 million metric tons in 1989. However, Ugo G. Stark, president of Akzo's fibers and polymers division, warns that the 1990 estimate may be slightly optimistic: It may not reflect actual performance in the Eastern European countries, especially the U.S.S.R. The other striking point, he adds, was the decline in output in most product areas in the U.S. and Western Europe. Some two thirds of all fibers used in the industrialized countries are synthetic fibers.

The breakdown of world production by region shows little change from 1989. While Western Europe, with 18% of total world production, remained at the level of the previous year, the share of the U.S. in world synthetic fiber production dropped a percentage point, to 20%, from the year before. Despite a 3% growth in such production in Japan, that country's world share remained at 9%. The dropped percentage point, in turn, was taken up by other producers throughout the world, whose combined share reached 53% in 1990.

Economic difficulties in the U.S. led to a large decrease in production. Output of cellulosic fibers decreased 7% and of synthetics 6%. In Western Europe, total synthetic fibers production increased slightly, although cellulosic fibers were off by 1%.

U.S. accounts for one fifth man-made fiber output



1990 production = 18.9 million metric tons

Source: Akzo fibers and polymers division

The 1980s saw emergence of a trend toward filament yarns and this continued in 1990, the company reports. Similarly, the trend continued toward polyester and "other synthetics," primarily polypropylene, and away from acrylics and nylon, or polyamide. World production of nylon declined 1% last year in nearly all regions, ranging from a 3% slump in the U.S. to no growth elsewhere. The sole bright exception for nylon was Japan, where production grew 3%.

Polyester output was nearly flat in 1990; filament yarns grew 3% and staple fibers declined 2%. The U.S. was hardest hit, with production declining 11%. However, in Japan production was up 6%, and in the rest of the world up 4%. These areas now make up almost 64% of polyester production in the world, and capacities in these regions are still being added at a rapid pace, Akzo points out.

Acrylics production also decreased in 1990, although the rate slowed somewhat to a 2% decline. Only Western Europe showed a gain in production.

And production of "other synthetics," mainly polypropylene, increased more than 10% in 1990 with all regions showing growth. Production of these fibers is mainly in the U.S. and Western Europe.

Cellulosic fibers production declined worldwide by 4% in 1990, with the decrease more pronounced in filament yarns, off by 6%, than in staple fibers, down 3%. The slowdown was most pronounced in the U.S., where production fell 7%. Output by other nations was down 6%.

Worldwide polyester output has increased 30% since 1985

Millions of metric tons	1990	1985	1980	19[illegible]5	1970
Cellulosics	**3.202**	**3.234**	**3.522**	**3.216**	**3.585**
Synthetics	**15.655**	**13.025**	**10.779**	**7.461**	**4.809**
Polyamide	3.757	3.387	3.234	2.462	1.924
Polyester	8.454	6.513	5.066	3.357	1.635
Acrylics	2.348	2.344	2.048	1.418	1.010
Other	1.096	0.781	0.431	0.224	0.240
TOTAL	**18.857**	**16.259**	**14.301**	**10.677**	**8.394**

The 6% drop was mainly attributable to production shutdowns in Eastern European countries. Environmental concerns in these countries make it doubtful that production will return to levels seen in the past, Akzo predicts.

At Akzo itself, fibers closed 1990 in a comparatively stable condition, says Stark. Performance varied considerably between the various regions and product groups, he says, but two thirds of the division's invested capital produced a return on investment that is "acceptable to very good." The remaining third consists of products still in development or startup or in problem areas, including carpet fibers and steel cord in Western Europe and Brazil.

Consolidated sales of the division in 1990 were $2.87 billion, 7% less than in 1989, mainly because of the lower level of shipments. Shipments totaled 400,000 metric tons, down 9% from 1989. Operating profits dropped 19% to $129 million. And capacity utilization in 1990 was about 84%, compared with 91% in 1989 and 1988.

Among the problem areas were carpet fibers, an area in which business was noticeably weaker, says Stark. Sales to Eastern Europe "were practically nil," and there was a general marked decline in exports to non-European countries. And in the loss-plagued steel tire-cord market, the company has decided to get out of the business; it will discontinue those operations by June.

Geographically, problems existed in Spain and Brazil. Spain is one of the weakest synthetic fiber markets in Europe, with a proliferation of many small manufacturing companies and, at present, an overvalued Spanish peseta, making cheaper imports attractive. The industry also has high financing costs, because of a 15% interest rate.

As for the Brazilian economy and the efforts the government there is making to stamp out inflation, according to Stark, the situation is very simple: "In the hands of our Lord." The economic problems of the country, sluggish sales to the local motor industry, and high financing costs had a serious effect on Akzo's earnings there last year.

Patricia Layman

David Alcorn receives marketing research award

The recipient of the Commercial Development Association's annual honor award, David S. Alcorn, told the group that "the successful commercial development manager in the future will have the ability to first define the needs of the customer and, second, to communicate this need clearly to the technical people in his organization. He thus becomes the initiator of research." Alcorn, vice president for dyes and chemicals at Crompton & Knowles, received the award at CDA's annual meeting in Philadelphia earlier this month.

As Alcorn noted in his award address, the commercial development manager is likely to have the title of marketing manager or product manager. In a small company, such a manager will truly be an entrepreneur, he says. The purpose of a commercial development manager today is to solve a customer's problem by selling an upgraded, more profitable product. And "while we may not be manufacturing or selling more pounds of product," he says, "in effect, we have added labor and cost to our starting product."

In this way, notes Alcorn, commercial development has come a long way from its initial phase in which chemists developed products, such as ethylene glycol, for which at first there were no commercial markets. Marketing meant publishing a chemical structure, giving away samples and hoping uses would develop. And they did. Ethylene glycol found use in antifreeze, explosives, resins, and fibers, notes Alcorn. In the second phase, market development managers began to sell products for specific markets such as solvents for coatings, vinyl plasticizers, and glycol antifreezes. "Instead of talking about chemical structures, we began using a new term—performance chemicals."

Although Alcorn notes that both commodity chemicals and performance chemicals are mature slow-growth markets now, growth in the third specialty phase "depends on the continuation of scientific research and the ability of creative commercial development people to do their job." He expects therefore that there will be no limit in the custom chemical manufacturing phase "based on the use of scientific knowledge to get improved products from limited raw materials."

A 25-year veteran of Union Carbide, who then joined J. T. Baker before his current tenure at Crompton & Knowles, Alcorn joins other past CDA award recipients such as Harold A. Sorgenti, president and chief executive officer of Arco Chemical; Air Products & Chemicals chairman and CEO Dexter F. Baker; and former Hercules chairman and CEO Alexander F. Giacco.

Also speaking at the CDA meeting was Madoka Tashiro, senior managing director of the Japanese chemical company Tosoh Corp., who pointed out that now is the time for western chemical concerns to secure a larger position in the Japanese chemical industry. There are no Japanese chemical companies among the 15 largest chemical firms worldwide and Japanese chemical firms do not have the global manufacturing and distribution abilities of competitors such as Dow Chemical, Du Pont, ICI, BASF, Bayer, and Rhône-Poulenc. Sumitomo, among the largest Japanese chemical concerns, has annual sales of about $6.5 billion, whereas the top 15 chemical firms' sales range between $9 billion and $26 billion. Tosoh itself has sales of about $3 billion.

Thus as Japanese domestic customers of chemicals for industries such as automotive and electronics globalize their production and search for chemical suppliers who can guarantee consistency and quality worldwide, the Japanese domestic chemical industry is at a disadvantage, says Tashiro. Japanese chemical companies must consolidate and form larger companies capable of expanding worldwide and investing the R&D dollars to support the development of new products as Tosoh itself is attempting to do. Alternatively, Japanese chemical companies will increasingly find themselves in positions where they must either sell out to, or form strategic alliances with, foreign chemical firms.

Marc Reisch

Job Security for Experienced Chemists Still Quite Vulnerable

There is both good news and bad news in the latest reports by the ACS Committee on Professional Relations (CPR) on the multiple termination of chemical professionals. The good news is that these reports, the 30th and 31st in a series dating back to 1974, each cover only three such incidents—the smallest number ever. They involve a total of 77 chemists and chemical engineers.

The bad news is that another 14 as yet unverified reports of such mass firings, involving as many as 350 chemical professionals, are under investigation. Another piece of news disturbing to CPR is that older chemists continue to bear the brunt of multiple terminations.

CPR defines a multiple termination as a situation in which the employment of three or more chemical professionals is terminated within a six-month period for reasons other than documented inadequate performance, completion of a contract, or cause.

In investigating multiple terminations, CPR seeks information from both terminees and employers. The committee believes the growing backlog of unconfirmed terminations is at least partly due to terminees' reluctance to cooperate with ACS. A related factor is an apparent increase in the use of secrecy clauses in individual termination agreements.

CPR is concerned that its conservative approach to reporting on multiple terminations may be understating the seriousness of the employment situation for chemists, especially older ones in industry. The committee has recently modified the questionnaire it sends to reported terminees in an effort to boost the low response rate.

The committee also may reconsider its guidelines on when it approaches an employer for details of a termination. The current practice is to do so only after reports from three individual terminees are in hand. To date, about two thirds of companies asked for such information provided it.

The six terminations detailed in the last two reports involved Allied-Signal, Bristol Myers, Chevron, DeSoto, Miles, and Reheis Chemical. They ranged in size from three chemists at Reheis to 30 at DeSoto. Another termination has been confirmed at PQ Corp., but this investigation is not yet complete.

As in previous reports, the performances of the employers involved were compared with standards contained in ACS's Professional Employment Guidelines (PEG). Five standards were used. They covered advance notice, severance pay, assistance in finding another job, extension of protection plans, and the involvement of longer term employees. Overall compliance was 53%. This was substantially higher than the average of 41% for the previous 29 reports.

The standard for longer term em-

Employer compliance with ACS employment guidelines

These employers provided information	Approximate number of employees separated	Advance notice	Severance pay	Assistance	Employee service	Protection plans
Allied-Signal (Morristown, N.J.)	14	☐	▨	☐	■	☐
Chevron (Richmond, Calif.)	6[a]	▨	☐	☐	▨	☐
DeSoto (Des Plaines, Ill.)	30	☐	☐	☐	■	☐
Miles (Elkhart, Ind.)	10	☐	☐	☐	■	☐

[a] Includes four concurrent retirements.

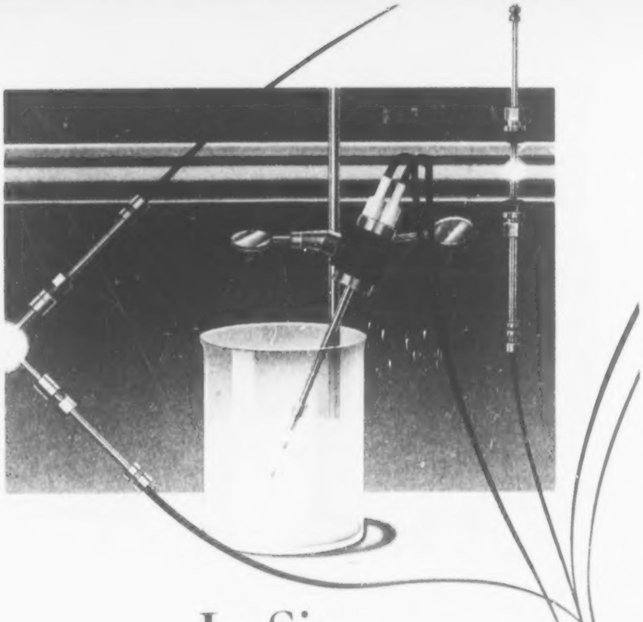
These employers provided no information	Approximate number of employees separated	Advance notice	Severance pay	Assistance	Employee service	Protection plans
Bristol Myers (Hillside, N.J.)	14	▨	☐	☐	■	▨
Reheis Chemical (Berkeley Heights, N.J.)	3	■	▨	■	■	▨

☐ Employer met or exceeded guideline standard.

▨ Two or more individuals below guideline standard, but average experience better than "substantially below" criterion.

■ Employer was substantially below guideline standard, which is defined as follows:

- Advance notice—less than two weeks.
- Severance pay—less than one week per year of service.
- Assistance—no assistance rendered.
- Employee service—more than 30% of terminees had 10 or more years of service.
- Protection plans—no continuation of protection plans.



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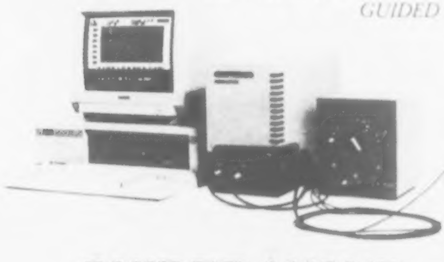

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CIRCLE 34 ON READER SERVICE CARD

ACS guidelines

Advance notice. Four-week minimum.

Severance pay. Minimum is two weeks per year of service. Additional notice may be given, by mutual agreement, in lieu of severance pay.

Assistance. Efforts should be made to place terminee in another position within the organization, or terminee should be given assistance to find employment elsewhere.

Pension plan vesting. Full vesting after five years' service.

Employee service. Those with minimum of 10 years' service should not be terminated except for continued evidence of previously documented inadequate performance or cause.

Employee protection plans. Should be extended for a minimum of one month, plus two weeks for each year of employee service, following termination, at same rate of contribution as before. Employee would have additional 31-day grace period.

ployees states that those with a minimum of 10 years of service should not be terminated except for inadequate performance or cause. For the about 250 terminations covered by all 31 CPR reports, it has been complied with only 22% of the time. But even this performance is declining. For the past nine reports dating back five years, only five of 60 employers complied.

All six employers covered in the last two reports violated this standard. Nine Bristol Myers terminees who reported to ACS had a minimum of 10 years of service and an average of 22. Similarly, 19 DeSoto terminees who reported to ACS had an average of 19 years of service.

Long-term compliance with the PEG standard of two weeks of severance pay for each year of service has not been good either, 22%. But in this case there is an improvement with 38% compliance over the past nine reports, including four of the six employers in the past two.

The standard calling for a mini-

Continued on page 72

J. Calvin Giddings wins 1991 Nichols medal

The ACS New York Section's William H. Nichols Medal will be presented March 22 to J. Calvin Giddings, Distinguished Professor of Chemistry, University of Utah, at the Nichols Distinguished Symposium, College of Mount Saint Vincent, Riverdale, N.Y. Giddings is being cited "for profound theoretical insights and outstanding innovations in separation science." The award is given annually to stimulate original research in chemistry.

Giddings received a Ph.D. in physical chemistry in 1954 under the direction of Henry Eyring. His thesis research dealt with topics in chemical kinetics, quantum chemistry, and chromatography. He did postdoctoral work on the theory of flames with J. S. Hirschfelder at the University of Wisconsin before joining the faculty at the University of Utah in 1957.

Winner of three ACS national awards, Giddings is recognized for research in almost all the fundamental aspects of chromatography. In 1967 he received the ACS Award in Chromatography & Electrophoresis; in 1980 the ACS Award in Analytical Chemistry; and in 1986 the ACS Award in Separations Science & Technology. He has also worked on the unification of separation theory, new separation methodology, electrophoresis, diffusion theory and measurement, and snow and avalanche physics. He invented, and with colleagues developed, the field-flow fractionation method for macromolecular separations.

Giddings authored "Dynamics of Chromatography" (1965); the 470-page textbook "Chemistry, Man, and Environmental Change" (1973); and the text "Unified Separation Science" (1991). In all, he has authored or coauthored more than 320 publications and edited 31 books. ☐

Special recognition to . . .

Daniel W. **Armstrong,** Curators' Professor of Chemistry, University of Missouri, Rolla, is the winner of the Martin Medal from the Chromatographic Society, Nottingham, U.K. He is being recognized for "his outstanding contributions to chromatography, particularly in the field of chiral discrimination." The award will be presented in May at the opening ceremony of the International Symposium on Chiral Discrimination in Rome.

Daniel **Bloch,** information and intellectual property manager, Johnson Wax, has received the ACS Milwaukee Section Award for "distinguished service to the profession of chemistry in the Milwaukee area." The highest honor awarded by the section, the award consists of a medal, a certificate and a stipend. Bloch is a past chairman of the Milwaukee Section, and is an adjunct professor of chemistry at the University of Wisconsin, Milwaukee.

Ajay K. **Bose,** George Meade Bond Professor of Chemistry, Stevens Institute of Technology, has been named 1990 New Jersey Professor of the Year by the Council for the Advancement and Support of Education. This award includes a $1000 prize sponsored by the Merck Co. Foundation. Bose is also the recipient of the Outstanding Achievement Award from the National Federation of Indian American Associations.

Stanley **Bruckenstein,** A. Conger Goodyear Professor of Chemistry, State University of New York, Buffalo, is the recipient of this year's Charles N. Reilley Award from the Society for Electroanalytical Chemistry. The award honors outstanding performance in electroanalytical chemistry. Bruckenstein was cited for being a pioneer in using very low level mass measurements to probe surface chemical and electrochemical reactions. He has used the technique to study many surface phenomena, including ion transport in conducting polymers.

Roberta F. **Coleman,** professor, department of chemistry and biochemistry, University of Delaware, is the winner of the ACS Delaware Section Award. She is being cited as "a leader in the field of enzyme structure, catalysis, and regulation." The pioneering research done in her lab has resulted in the synthesis and application of new purine nucleotide analogs that mimic naturally occurring compounds but are capable of reacting covalently at specific sites in enzymes and receptors. The award consists of a plaque and a stipend, and is given annually "to recognize conspicuous scientific achievement and contributions in an area of chemistry or chemical engineering by a member of the Delaware Section."

Lori **Engel,** University of Florida, Gainesville, is the winner of the 1990 Sherwin-Williams Student Award in Applied Polymer Science. This award is sponsored by Sherwin-Williams and administered through the joint Polymer Education Committee of the ACS divisions of Polymeric Materials: Science & Engineering and Polymer Chemistry. Engel, who is working toward her Ph.D., won for her paper, "Thermally Reversible Covalent Polymer Linkages I. Model Studies of the Azlactone Ring."

Allan S. **Hoffman,** professor of bioengineering and chemical engineering, University of Washington, has received the 1990 Biomaterials Science Prize from the Japanese Society for Biomaterials. This award is in recognition of "distinguished service in the advancement of biomaterials science." Hoffman is the first foreigner to receive the award, which was presented to him in Tsukuba, Japan. ☐

ACS News

Continued from page 68

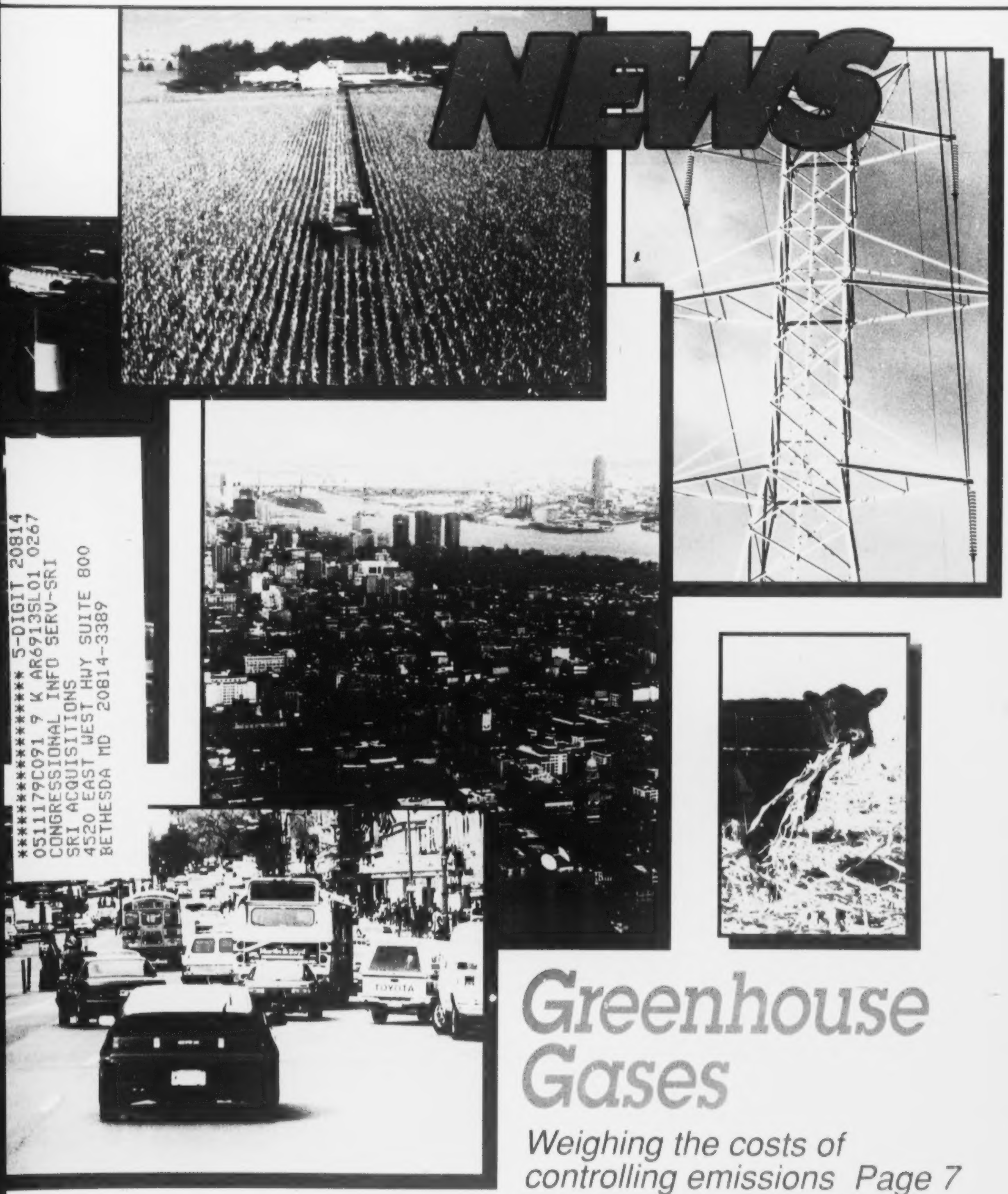
mum of four weeks of advance notice was complied with in three of the six terminations covered in the past two reports. Long-term compliance is 40%. Long-term compliance with the requirement to extend employee protection plans beyond actual termination is at 50%, and 71% have met the standard for providing aid in finding another job.

Copies of termination reports as well as a summary of all terminations are available on request from the American Chemical Society, Office of Professional Services, 1155 —16th St., N.W., Washington, D.C. 20036.

Michael Heylin

APRIL 1, 1991

CHEMICAL & ENGINEERING NEWS



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Greenhouse Gases

Weighing the costs of controlling emissions *Page 7*

CHEMICAL & ENGINEERING NEWS

Volume 69, Number 13
CENEAR 69 (13) 1–64
ISSN 0009-2347

APRIL 1, 1991

News of the Week

- **Outline for a research program to study multiple chemical sensitivity was agreed upon during recent NAS-sponsored workshop.** Page 4
- **Scientists assail NASA's plan, submitted to Congress, for a smaller, extensively redesigned space station *Freedom*.** Page 5
- **1990 pretax profits down sharply for Germany's Big Three chemical companies.** Page 6
- **FDA suggests "expanded access" for patients to Warner-Lambert's experimental drug tacrine, a promising treatment for Alzheimer's disease.** Page 6

Business

Customer-supplier partnerships are becoming more commonplace in the chemical industry, largely because of increasing competition among chemical companies. **Page 17**

Revenues rose for some biotech firms in 1990, but, as in 1989, very few were profitable. **Page 21**

Capacity for benzene, *p*-xylene, other major aromatics will outpace demand well into the mid-1990s. **Page 23**

Government

Proposed user fees for Department of Energy labs have been criticized as unworkable and counterproductive in recent House hearings. **Page 26**

Science/Technology

Dispersion method that emits controlled amounts of atmospheric gases may give clue to CO_2's effects on biomass. **Page 29**

First evidence of ^{4}He formation in "cold fusion" cell produced by chemists at California's Naval Weapons Center. **Page 31**

Strategy that redirects immune response, introducing potential new immunotherapeutic method, developed by Berkeley chemists. **Page 33**

NASA's Hubble Space Telescope begins program to monitor Mars' seasonal and annual changes. **Page 34**

ACS News

Staff operations have been reorganized at ACS in move to serve the membership more effectively. **Page 37**

News Focus

Global climate change policies increasingly are being analyzed from an economic standpoint, while modelers struggle to forecast cost-benefits of emissions controls. **Page 7**

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Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
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Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Sharing credit

The announcement of the Wolf Prize in Chemistry (C&EN, Jan. 14, page 22) attributes cross-polarization magic-angle spinning to Alexander Pines working with John Waugh. In fact, it is well known that Jacob Schaefer, Samuel Weissman, and Edward Stejskal were the first to employ magic-angle spinning for carbon-13 in solids. The historical context of cross-polarization nuclear magnetic resonance has been discussed on many occasions, most recently in "Current Contents" (Proton-enhanced NMR of dilute spins in solids, Citation Classics, in press).

A. Pines
Berkeley, Calif.

Risk assessment of pesticides

The News Forum, "Risk Assessment of Pesticides" (C&EN, Jan. 7, page 27) contains a rebuttal by Joseph K. Haseman and James E. Huff that is headlined, "Arguments that discredit animal studies lack scientific support." That oversimplified headline and its amplification in the text should not go unanswered. The detailed answers are contained in the proceedings of three symposia and a book of invited presentations:

- A January 1986 Food & Drug Administration-sponsored symposium (conducted by the Federation of American Societies for Experimental Biology) on "Biological Bases for Interspecies Extrapolation of Carcinogenic Data." Copies of the proceedings are available from FASEB, 9650 Rockville Pike, Bethesda, Md. 20814.
- "Proceedings: New Directions in the Extrapolation of Health Risks from Animals to Man." Vol. I, "Extrapolation from Animals to Man." Vol. II, "Toxicokinetics." Electric Power Institute (1986). Request copies from Research Reports Center, P.O. Box 50490, Palo Alto, Calif. 94303.
- "Human Risk Assessment: the Role of Animal Selection and Extrapolation," M. V. Roloff, Editor, Taylor & Francis, London (1987).
- "Proceedings of the Pharmacokinetics in Risk Assessment Workshop" (Oct. 1986). "Drinking Water and Health." Vol. 8, "Pharmacokinetics." National Academy Press, Washington, D.C. (1988).

In addition, several professional advisory groups have expressed reservations concerning the validity of relating results of chronic studies with animals to effects on humans exposed to the chemical studied. The American Medical Association's Council on Scientific Affairs expressed concern [*J. Am. Med. Assoc.* **246**, 253 (1981)] "about the hundreds of millions of dollars that are spent each year . . . for carcinogenicity testing of chemical substances . . . in view of the questionable scientific value of the tests when used to predict human experience."

An interagency staff group in a review document [*Fed. Reg.*, **49**, 21594 (1984)] prepared for the President's Office of Science & Technology Policy noted that "while there is a significant amount of evidence to support qualitative animal to human extrapolation for carcinogenesis, the evidence falls short of establishing this proposition as a scientific fact. . . . This principle [that an animal carcinogen should be considered a suspect human carcinogen] has been accepted by all health and regulatory agencies and is regarded widely by scientists in industry and academia as a justifiable and necessary interference." An Interdisciplinary Panel on Chemical Carcinogenicity, convened at the request of the American Industrial Health Council, advised [*Science*, **225**, 682 (1984)] that "data derived from animal studies, although suggestive of carcinogenic risk, may require additional study before extrapolation to conditions of human exposure can be made. Interpretation of . . . different patterns of tumor development in test animals should recognize the likelihood that these represent different mechanisms and may have different significance to human risk."

And finally, a Subpanel on Design of Chronic Studies in a 1984 report of the National Toxicology Program Ad Hoc Panel on Chemical Carcinogenesis Testing and Evaluation "stressed that . . . extrapolation from species to species and from rodents to man are generally carried out for public health purposes; they do not necessarily imply extrapolation on a scientific basis in all respects for each species. Such estimates are often required to meet societal needs, and are subject to change when further scientific information becomes available."

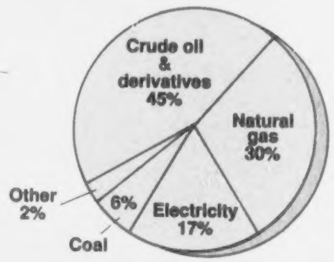
In brief, the argument is not against studies with animals, but in the way they are interpreted. The argument is against the simplistic counting of lesions. As stated by a pioneer toxicologist-biochemist, Bernard Oser [*J. Toxicol. Environ. Health*, **8**, 521 (1981)], "We should take into account the differences between humans and rats when we plan and interpret studies in rats, and not fall into the trap of replacing good judgment

Greenhouse gas controls could hit chemical industry hard

The U.S. chemical industry—which relies on fossil fuels not only for fuel and power, but also for raw materials—is one of the most energy-intensive manufacturing groups. According to the Chemical Manufacturers Association (CMA), the U.S. industry's 1989 energy consumption of about 5.3 quadrillion Btu was about 7% of the U.S. total.

The chemical industry is the single largest user of natural gas in the nation, consuming about 10% of the total, CMA says. And it uses about 6% of all petroleum products consumed in the U.S.

Chemical industry relies heavily on oil and gas



Total 1989 consumption = 5.3 quads

Note: Consumption includes feedstock as well as fuel and power. Quad = quadrillion Btu.
Source: Chemical Manufacturers Association

So if the U.S. chooses a strategy of limiting greenhouse gas emissions through increased energy prices, the impact of higher energy costs could hit the chemical industry hard. It uses relatively little coal, the energy source that will increase most in price if a carbon tax is instituted. But competition from other energy consumers switching away from coal will force up the prices of oil and gas.

However, several factors unique to the industry could ease the pain, says Marc H. Ross, professor of physics at the University of Michigan, Ann Arbor. Ross, who analyzes both the technical and policy aspects of industrial energy use, is currently on sabbatical at Lawrence Berkeley Laboratory.

"The chemical industry may be in a better position than most," Ross says. "There is so much technical capability within the industry. Chemical engineers are trained to study the flow of energy and materials. The industry has been one of the most successful in reducing energy intensity in the past."

The industry's well-established pattern of growth will help, Ross adds, pointing out that new plants are more energy-efficient than old ones. So will continuing process improvements: New developments in catalysis, sensors, and control systems all should contribute to decreased energy demand.

And most industrial chemistry processes are still very far from thermodynamic limits in efficiency, he says, if one compares the ratio of energy used to the minimum required. "In cases where heat is required we use much more energy than theoretically necessary. And in principle we could extract energy from energy-releasing reactions."

The ongoing diversification of the chemical industry means that some firms would be affected by greenhouse gas controls in their roles as energy suppliers as well as energy consumers. Du Pont, for example, produces not only chemicals but also coal and oil.

"Global warming itself is a concern to Du Pont," says W. Ross Stevens III, manager of environmental affairs for the company. "And concerns over the economic impacts of controls are very real to us. We want to be sure rational choices are made. At the same time, we are aware carbon dioxide needs to be controlled."

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urban poor because of heat stress and changes in the availability of water and food.

If such predictions turn out to be correct, the greatest economic damages from global warming will hit the countries that have the fewest resources to deal with them. Third World nations are already short of money for the conventional technologies needed to raise their standards of living, notes Mohan Munasinghe, the World Bank's division chief for environmental policy. Their plight is made that much worse by adding the costs of environmental damages.

Because the costs of controlling greenhouse gas emissions would be borne primarily by the industrialized world, while the benefits of avoiding the damages of global warming would be realized mostly in developing countries, the internal cost-benefit analyses of the U.S. and other developed countries may well show the costs outweigh the benefits.

That is one of the reasons Peter G. Brown, professor of public affairs at the University of Maryland, argues against addressing the issue in terms of costs and benefits. "That strategy is not appropriate to issues of planetary management," he says. Instead, Brown believes, humans have an obligation to conserve the options and quality of life available to future generations, never mind the cost.

Paul R. Portney, an economist who is vice president of Resources for the Future, a Washington-D.C.-based think tank, conceded in summing up the cost conference that cost-benefit analysis alone is inadequate to address the scope of global climate change. "We cannot now and never will satisfactorily express in dollars all the costs and benefits of control measures," he said. He noted that GNP falls short of measuring the health of an economy because it doesn't count many things people value, such as leisure and environmental quality.

"Any economist who says that a policy isn't good because GNP will go down doesn't deserve your attention," Portney went on. "Nevertheless, it's useful to think about what we will get if we pursue a specific policy and what we will have to give up.

"Is the trade-off worth it? What protections will we get if we try to stabilize climate rather than investing in a host of other problems—education, for example?"

Indeed, that is the question. Unfortunately, neither economists nor scientists yet have the answer. □

Revenues grow for some biotech companies

Ann M. Thayer,
C&EN Northeast News Bureau

In 1990, as in 1989, very few biotechnology companies broke from the ranks to become profitable. Of the 33 companies surveyed by C&EN, only six reported modest profits for the year. Revenues rose substantially for many companies but for only a few because of product sales. Although biotechnology products are beginning to reach the market, and more are expected to make it past regulatory obstacles in the next few years, the high costs of R&D and commercialization continue to take a large bite out of earnings.

Product sales for the biotechnology industry are dominated by human therapeutics and diagnostics. Agricultural companies have yet to market a major biotechnology-based product. Companies such as Ecogen, Mycogen, Calgene, and Crop Genetics—not unlike small biotechnology drug companies—continue to work on raising capital, developing products, and putting together strategic alliances to help enter the market. Sales of biopharmaceuticals reached about $1 billion in 1990, according to the San Francisco-based investment firm of Hambrecht & Quist, and could reach $2 billion by 1992.

With tissue plasminogen activator (TPA) and human growth hormone (HGH), Genentech had product sales of $367 million, a 15% growth over 1989. This was due primarily to growth in HGH sales, rather than from TPA sales, which are facing increased competition. Despite this, Genentech reported a loss of $98 million, attributed to a special charge of nearly $168 million related to its merger with Roche Holdings.

Coming into prominence in 1990 as a fully integrated biopharmaceutical company was Amgen. With its single erythropoietin (EPO) product, the company had sales of $281 million. Again, a special charge of $50 million for the acquisition of certain patent rights left Amgen with net earnings of only $3.9 million.

Revenues for Biogen, which reached $59.4 million, were largely royalty income from licensees' sales of several major products, including hepatitis B vaccine and diagnostics, and α-interferon. In 1990, the company reported its second consecutive profitable year. Chiron had its first profitable year with strong revenues from its joint blood screening and diagnostics business with Ortho Diagnostics. Other profitable companies include Applied Bioscience, an R&D services company; Immucor, a supplier of blood bank reagents and related products; and Collagen, which produces collagen-based biomedical products. Immunex, although not profitable in 1990, is in the process of launching its first product this year.

For the majority of companies, revenues come from contract or collaborative R&D. Several companies with near-term products, such as Centocor and Xoma, are expected soon to make the transition from R&D to marketing. In the meantime, they, along with Cytogen, Genetics Institute, and Cetus, reported sizable losses. This is not surprising, as these companies have been investing in product development, clinical trials, and marketing to prepare for the launch of their first drug products in the U.S.

Few biotech firms were profitable in 1990

			Change from 1989		Profit margin[b]	
$ Thousands	Revenues[a]	Earnings	Revenues	Earnings	1990	1989
Amgen	$300,809	$3,865	102%	3%	1%	3%
Applied Bioscience	99,650	8,149	- 27	34	8	8
Biogen	59,415	7,720	45	140	13	8
BioTechnology General	4,307	−6,217	−12	def	def	def
Calgene	32,904	−13,195	3	def	def	def
California Biotechnology	12,425	−5,131	0.5	def	def	def
Cambridge Biotech	21,854	−10,396	−6	def	def	def
Centocor	64,634	−132,180	−10	def	def	0.2
Cetus	46,765	−71,780	53	def	def	def
Chiron	78,512	6,829	121	def	9	def
Collagen	58,309	3,184	23	−12	6	8
Cytogen	4,701	−17,339	−37	def	def	def
DNA Plant Technology	13,427	−8,939	4	def	def	def
Ecogen	2,188	−7,968	−26	def	def	def
Enzo Biochem	20,962	−4,642	3	def	def	def
Genentech	476,136	−98,031	19	def	def	11
Genetics Institute	40,374	−22,873	−8	def	def	def
Genzyme	54,835	−4,542	60	def	def	def
Immucor	14,946	2,507	37	45	17	16
Immunex	34,879	−9,887	24	def	def	def
Immunogen	3,126	−7,621	297	def	def	def
Immunomedics	4,395	−2,573	60	def	def	def
Liposome	7,071	−5,005	88	def	def	def
MGI Pharma[c]	6,364	−6,429	33	def	def	46
Mycogen	14,980	−4,492	47	def	def	def
NeoRx	1,745	−16,055	−72	def	def	def
Nova Pharmaceuticals	36,095	−14,245	130	def	def	def
Oncogene Science	5,345	−3,478	20	def	def	def
Repligen	10,703	−5,702	−11	def	def	def
Ribi ImmunoChem	1,317	−2,715	6	def	def	def
Synergen	12,746	−6,412	−14	def	def	def
T Cell Sciences	12,042	−2,215	10	def	def	def
Xoma	20,476	−23,676	97	def	def	def

a Includes product sales, contract research, royalty, and interest revenues for calendar year. b After-tax income as percentage of sales. c Name changed from Molecular Genetics. **def** = deficit.

Xoma and Centocor are awaiting Food & Drug Administration approval for monoclonal-antibody-based products used to treat bacterial sepsis or septic shock. With a market estimated at more than 400,000 patients, product sales are expected to do much to contribute to revenue growth and eventual profitability for either company. Centocor recently received approval in Europe. Yet to be resolved is a patent suit between the companies. In 1990, Centocor reported a loss of $132 million, having spent $115 million to reacquire rights to three products.

Another firm with a sizable loss is Cetus, which lost nearly $72 million. Cetus' much publicized problems with launching its interleukin-2 in the U.S. led to cost cutting, staff reductions, and management changes in 1990. On the positive side, Cetus' patents to polymerase chain reaction technology were recently upheld. In addition to an internal business area, PCR forms the basis of two joint ventures for the company.

Genetics Institute had major setbacks on two fronts, having been found to infringe Genentech's patents on TPA and Amgen's patent on EPO, while having its own EPO patent declared invalid. With no products on the U.S. market, Genetics Institute's short-term revenues come in part from sales of EPO overseas by licensees. Adding to this may be royalty income from Factor VII, licensed to Baxter Healthcare and pending FDA approval, from granulocyte macrophage colony-stimulating factor (GM-CSF), also awaiting approval and to be comarketed by Sandoz and Schering-Plough under license from Genetics Institute.

Just recently approved are two competing products—Amgen's G-CSF and Immunex's GM-CSF. The market for G-CSF, approved for the treatment of white blood cell deficiencies in patients undergoing cancer therapy is estimated to have as many as 250,000 patients and as much as $200 million in sales within a few years. Approvals of the CSFs mark the first in a major new class of biopharmaceuticals estimated to be worth as much as $1 billion in sales by the mid-1990s.

The CSFs—together with Genentech's γ-interferon, which was the only biopharmaceutical to be approved in 1990—are the first among what is believed will be a growing number of biotechnology drugs reaching the market in the 1990s. To date, only 14 biotechnology drugs have been approved but more than 100 products, developed by nearly 40 companies, are in clinical trials or awaiting approval.

Recent approvals of major products are focusing investor attention on promising biotechnology companies. Both Amgen's and Immunex's stock prices jumped dramatically after receiving FDA approval for their products. Patent issues also have an impact. Amgen's share price continued to rise following the outcome of the EPO patent trial, whereas Genetics Institute's share price dropped about 30%. Similarly, Cetus saw a large drop in the value of its stock when an FDA advisory committee failed to recommend approval for IL-2.

In late February and early March, biotechnology stock prices overall rose in light of renewed interest by investors. Riding this wave, several companies recently have announced public offerings of stock. In 1990, biotech stocks outperformed the stock market. According to Hambrecht & Quist, the value of biotechnology stocks as a group grew about 37%, whereas the Dow Jones Industrial Average fell just over 4%.

Although increased product sales signal growth, they also are expected to contribute to new problems facing the biotechnology industry. Reimbursement is considered a major issue of the 1990s in a survey of companies by the San Francisco-based management consulting firm Ernst & Young. "The products of biotechnology are coming into use just as the health care environment is undergoing drastic change. Government reimbursement authorities, private insurers, and corporate benefits departments all are engaged in initiatives to impose control over upwardly spiraling costs." The challenge for biotechnology companies, adds Ernst & Young, is to definitively demonstrate the value of products beyond the routine questions of safety and efficacy, providing cost-effectiveness and cost/benefit ratios, and documenting products' impact on patients' quality of life.

"There is no question about it—the drugs we are producing are truly revolutionary. They offer physicians therapeutic modalities that in some ways were never dreamed and have very attractive side effect profiles," says Harry F. Hixson Jr., until recently the president of Amgen. "But the cost of new products is not a major contributor to the overall cost of health care."

Like most biotech companies, Amgen had to raise hundreds of millions of dollars in investor capital, explains Hixson, and just now is putting a second product on the market. Thus product pricing not only takes into account existing product competition and reimbursement pressures, but also aims to recover development, marketing, and manufacturing costs, to generate capital to fund R&D for future products, and to provide shareholders with a return on their investment.

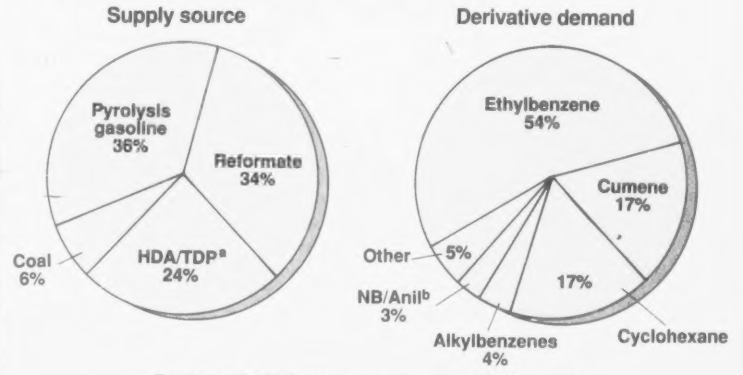
With U.S. sales expected to exceed $300 million this year, EPO pricing and reimbursement have been investigated by the Department of Health & Human Services. Pricing was approved by the Health Care Financing Organization under a program for dialysis patients. Considering the improved quality of life for dialysis patients on EPO, its cost is "not inappropriate," says Hixson. Amgen's second product, G-CSF, and additional uses for EPO will not fall under such programs. Companies also stress the ability of such drugs to decrease overall treatment time and cost.

EPO's approved use has been expanded to include the treatment of anemia in AIDS patients, a market being handled by Amgen's licensee, Ortho Biotech. The AIDS area is one already confronted with issues surrounding high-priced drugs. A program to supply EPO free of charge to those who can't afford it or to cap the cost at $8500 per year for those requiring large quantities of drug has been set up, explains Dennis Longstreet, president of Ortho Biotech. Such programs are not uncommon—Amgen has a similar program for EPO and Genentech has programs to make its products available. Hoffmann-La Roche has a program that caps costs for α-interferon, used to treat AIDS-related Kaposi's sarcoma, at $9800 per year. □

Aromatics demand to lag capacity growth

Bruce F. Greek, C&EN Houston

Global benzene supply/demand for mid-1990s



Projected 1996 consumption = 8.4 billion gal

a Hydrodealkylation or disproportionation of toluene. b Nitrobenzene and aniline.
Source: Chemical Marketing Associates

Overcapacity of major aromatic chemicals likely will plague producers throughout the world well into the mid-1990s, according to marketing experts meeting last month in Houston at a seminar entitled "Petrochemical Forecasts in an Uncertain World." Sponsored by consultant company Chemical Marketing Associates Inc. (CMAI), seminar participants also predicted that aromatics demand will grow at moderate rates but supply from new plants and shifts in gasoline formulations will hold down plant utilization rates despite scrappage of some production units.

Earnings from these aromatics are expected to drop this year and next, and then to recover later on. Profit margins this year for aromatics and other chemicals likely will be better than the demand-capacity relationship would indicate, because of lower prices for crude oil.

Prices of crude oil, from which some aromatics are derived, will increase on the average during 1992 and will continue to rise as worldwide economic growth boosts energy demand, says Arved Teleki, president of Hydrocarbon Consultants in Houston. Because of environmental constraints on the use of coal, nuclear power, and hydropower, the slow growth in energy conservation programs, and instability in the Middle East, oil and gas will meet much of the load of growing energy demand. Consequently, petrochemical producers will have to pass on the costs of feedstock and energy or face lowered margins.

Teleki forecasts that in 1996 the average refinery acquisition cost of crude oil will reach $36.50 per barrel in current dollars, which is higher than the all-time high of $35.24 in 1981. In constant 1990 dollars, he says, the 1996 price would translate to about $30 per bbl, compared with the 1981 price of $50 per bbl in 1990 dollars.

Among the basic aromatics, benzene demand will continue to grow following a slowdown this year. Through 1996, global demand will average 4.1% annual growth, says Mark A. Fisler of CMAI. U.S. demand alone will grow 4.3% per year, spurred by a continuing increase in the use of benzene to make ethylbenzene, he says. That use will grow an average of 5.4% annually.

In Japan, growth in benzene use, at 3% annually, will remain below the world rate, says Fisler. Growth in Japan is being stifled by the rapid increase in capacity in the Pacific Rim outside Japan. Shifting feedstocks from benzene to toluene to make cumene also causes a decline in this use of benzene.

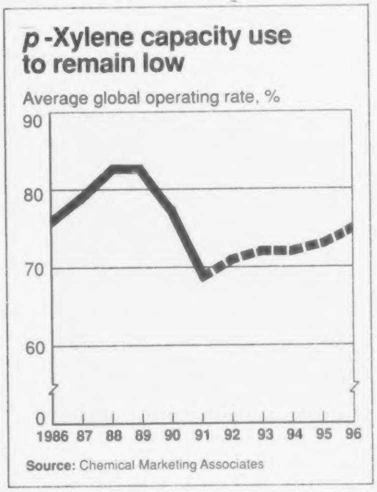
A shift in making adipic acid directly from benzene also will cause another application of benzene, that of making cyclohexane, to fall. This decrease will be offset by a significant jump in the all-other uses category. Japan also will encounter a major overcapacity situation if all of the proposed toluene dealkylation capacity is built on schedule before 1996.

The other Pacific Rim countries, as well as Australia, China, and India, will support benzene growth of more than 13% annually through 1996. Much of the growth will be the result of increasing demand to make ethylbenzene for styrene. Meeting the demand for making derivatives could require increasing benzene imports to continue into, for example, South Korea. Behind these continuing imports are optimistic expectations of the amount of benzene to be obtained from pyrolysis gasoline as a coproduct in the making of ethylene. Low benzene production may result from any construction delays and operating problems with steam crackers in South Korea.

In Western Europe, demand for benzene will grow about 2.5% annually between 1990 and 1996. The lower rate could result partially from inclusion of East Germany's production and consumption into Western Europe totals. Another cause for lower growth stems from slowing demand for ethylbenzene, says Fisler. Shifting from benzene to *n*-butane as the feedstock for making maleic anhydride in Europe also is a contributing factor in the slower growth.

Some unusual changes in the benzene business are expected to come from implementation of the Clear Air Act amendments. For example, the use of more oxygenated compounds in gasolines may lead to a surplus of higher octane hydrocarbons, such as the aromatics, and to lower and more stable prices for these hydrocarbons.

The economics of hydrodealkylation of toluene to benzene will continue to set the basic floor price for


p-Xylene capacity use to remain low

Source: Chemical Marketing Associates

benzene, but fewer and less dramatic price fluctuations will occur, according to Fisler. If catalytic reformers are operated less severely to reduce aromatics production because the demand for octane values is offset by the oxygenates, less coproduct hydrogen will be made. Therefore, pressure to find hydrogen will affect economics of both hydrodealkylation and manufacture of cyclohexane.

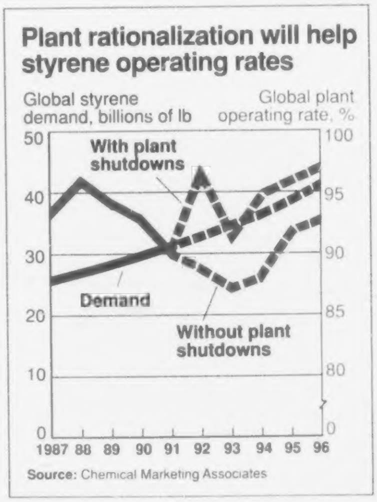
Another basic aromatic facing rapidly increasing overcapacity is *p*-xylene, Graham Copley of CMAI Europe told the seminar. Large additions to capacity are driving down average plant operating rates even as global consumption rises. In 1991, the rate will fall below 70% before beginning a slow climb up to about 77% by 1996. The operating rate in the U.S. will continue to drop from more than 93% in 1988 to under 75% in 1992, before it resumes a climb, possibly spurred by closing of some capacity in 1993.

After climbing in the second quarter of 1990 and then declining late in the year, pricing of *p*-xylene in the future will vary with several possible scenarios. The need for aromatics in gasoline influences pricing. This results in a floor on *p*-xylene prices based on the value established for the mixed xylenes stream from which *p*-xylene is extracted. Mixed xylenes are valuable because they can be blended into gasoline, Copley points out. That value may be reduced if the aromatic content of gasoline is reduced as a result of reformulation. If use of mixed xylenes is reduced, then low prices for *p*-xylene probably would make it unprofitable to recover mixed xylenes from reformate or pyrolysis gasoline. Mixed xylenes could reach a value close to that of naphtha, a feedstock for steam cracking.

Copley forecasts that contract prices for *p*-xylene then would be in the area of about break-even cash margins, or in the range of 15 to 20 cents per lb this year, rising to around 30 cents per lb in 1996. To cover capital replacement, prices would have to be 8 to 10 cents per lb more. Most U.S. and Western Europe *p*-xylene capacity now is fully depreciated, and producers will not show a loss if the mixed xylenes feedstocks cost as little as gasoline blending alternatives or less.

Need for capacity and high profitability from making styrene in the late 1980s led to a remarkable amount of new capacity being planned for the short and long term, Steve A. Knight of CMAI told the seminar. Capacity in the world, if all plans are completed, will increase from about 14.7 million metric tons in 1990 to more than 20 million metric tons in 1996. A more pressing problem is that more than 75% of the additional capacity for the monomer is planned to be operating by the end of 1993.

Some shuttering of capacity may occur because of the overcapacity. Decisions to shut down capacity will be based on upstream and downstream integration, location, and economic factors, Knight says. For example, some 200,000 metric tons of U.S. capacity is considered almost certain to be closed because it is old, inefficient, and lacking integration.


Plant rationalization will help styrene operating rates

Source: Chemical Marketing Associates

Growth in demand for styrene will be relatively low in the U.S. For 1990 to 1996, Knight forecasts growth of 3.8% per year. But, if the years of slightly declining demand—1989 and 1990—are included, then the average growth rate between 1988 (the previous peak year at 8.1 billion lb) and 1996 will be just 2.2% per year.

Exports of styrene are forecast to help keep plant operating rates going up. The new highly competitive capacity of the U.S. will keep U.S. exports strong as demand grows in developing countries.

Global demand for styrene is forecast by Knight to exceed 41 billion lb in 1996, up from 26 billion in 1987. Growth between 1990 and 1996 will average 5.3% annually. Even if no obsolete styrene capacity is shut down, plant operating rates will increase after 1993, from a low expected of about 87%. Rationalization of styrene capacity could reverse the drop in operating rates expected next year. Then shutdowns would be more than offset by new capacity, with the rate declining in 1993, before climbing back to 97% of capacity in 1996.

Profit margins in cents per pound for styrene will not return to the almost unprofitable levels of the early 1980s. However, they will fall substantially from the range of 10 to 20 cents per lb between 1987 and 1990. Margins likely will bottom out at around 2 cents per lb next year for contract sales, Knight expects. Export or spot margins then also will return to higher levels after declining to almost nothing this year.

This lower profitability now faced by styrene makers will inhibit planning for new capacity in the 1992 to 1994 period, says Knight. Therefore, he expects to speak at a CMAI seminar in 1996 with a title something like "Styrene—Too Much Demand, Too Little Capacity." □

APRIL 8, 1991

CHEMICAL & ENGINEERING NEWS

Top 50 chemical products
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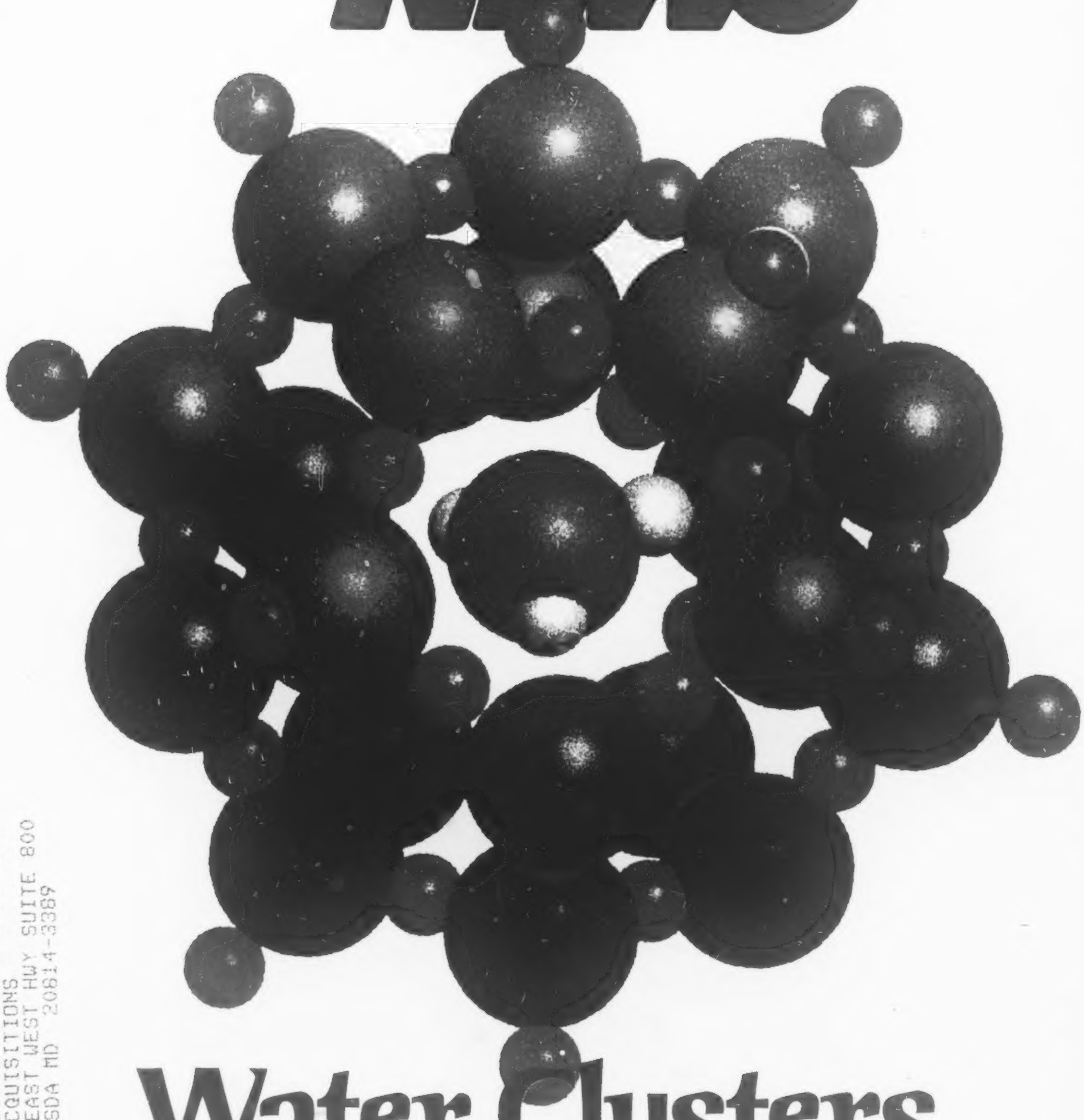

Water Clusters

Researchers probe architecture and stability
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CHEMICAL & ENGINEERING
NEWS

Volume 69, Number 14
CENEAR 69 (14) 1–78
ISSN 0009-2347

APRIL 8, 1991

News of the Week

- **International companies and industrial organizations meeting this week in the Netherlands will take pledge of environmental responsibility.** Page 4
- **Elsevier buys Pergamon Press, consolidating two big scientific publishers.** Page 5
- **Himont chairman Alexander F. Giacco starts $200 million venture in plastics with two top executive partners.** Page 5
- **Erythromycin derivative with increased stability under acidic conditions is produced by target mutagenesis.** Page 6
- **Rohm & Haas chairman J. Lawrence Wilson speaks on recruitment and hiring of blacks to black chemists and chemical engineers meeting last week in Washington, D.C.** Page 6

Cover: A computer-generated model of the structure of the water cluster $H^+(H_2O)_{21}$ shows the H_3O^+ ion encaged inside the pentagonal dodecahedron. The red balls represent nonhydrogen-bonded atoms. The small green balls are the hydrogen-bonded hydrogen atoms. The large balls are the oxygen atoms. Photo courtesy of A. Welford Castleman Jr., Pennsylvania State University

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Business

Top 50 chemicals recovered in 1990 from significant slowdown in 1989, rising 2% to an all-time high of 626 billion lb; overall output of polymers increased 4.3% in 1990 to a record 61.6 billion lb; petroleum refiners call for increased "environmental literacy" to meet environmental challenges of the 1990s; plastics industry offers major recycling plan in attempt to develop realistic solutions to disposal. **Page 13**

Government

Tacrine, a potential Alzheimer's treatment, stirs controversy as it wends its way through FDA's approval process; Margot O'Toole, whose allegations triggered a major scientific misconduct investigation, looks on as "Baltimore affair" nears end; discontent among academic researchers is at all-time high as they deal with issues of research ethics, funding, and technological competition. **Page 30**

Science/Technology

U.K.'s Royal Society of Chemistry celebrates 150th anniversary; 3-D structure of RNase H, key in life cycle of HIV, unraveled; thin films of fullerenes produced by doping. **Page 50**

Education

Analytical chemistry is no longer just for chemists at the University of Wisconsin, Madison, which has redefined it both to expand its horizons and attract nonchemistry majors. **Page 63**

Perkin Medal

Squibb's Miguel A. Ondetti, who led the group that discovered the hypertensive drug captopril, wins 1991 Perkin Medal. **Page 64**

Cover Story

Definitive evidence found for structure of 21-unit water cluster that contains hydronium ion at its core. **Page 47**

Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
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PUBLISHING BOARD: Jean'ne M. Shreeve (*Chairman*); *Board of Directors Chairman:* Joseph A. Dixon; *President:* S. Allen Heininger; Richard L. Deming; William P. Jencks; Gary J. Long; and Louis D. Quin

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Subscription Rates 1991. Printed editions: nonmembers U.S. 1 yr. $95, 2 yr. $171; outside U.S. 1 yr. $131, 2 yr. $243. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $12. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Ozone depletion

Your article on Union Carbide's new plants in Kingman, Ariz. (C&EN, Jan. 7, page 15) quotes Carbide plant manager, Frank Gasser, as saying to his citizen opponents, "If they promised not to maximize the dangers, . . . we wouldn't minimize the risks." Later, your writer says, "What has exasperated Carbide is the knowledge that CFC-12—as opposed to the more potent CFC-113 for example—is merely a minor player in the degradation of Earth's ozone layer." Far from being a minor player, CFC-12 is the most abundant chlorofluorocarbon in the atmosphere, the number one source of man-made chlorine in the stratosphere, and therefore a very major player in stratospheric ozone depletion.

Furthermore the ozone depletion potential of CFC-12 is actually somewhat greater than that of CFC-113 (e.g., 1.0 versus 0.82 in the Lawrence Livermore 1-D model).

F. Sherwood Rowland
Professor of Chemistry
University of California, Irvine

What is a chemical?

In some recent issues of C&EN there have been proposals to substitute innocuous terms for the word chemical, in order to improve the public opinion of chemistry. This strikes me as the confusion of image with reality that replaced War Department with Department of Defense.

Chemistry, in both academic research and industrial production, produces, concentrates, and releases into the environment unpleasant, dangerous chemicals. Calling them compounds or substances doesn't alter their impact on people's lives. If members of the public have never heard of beneficent man-made chemicals or harmful natural ones, whose fault is that? We are the experts, the teachers, and the teachers of teachers.

Marya Lieberman
Department of Chemistry
University of Washington, Seattle

Reduced grant awards

The Government Concentrates section (C&EN, Jan. 28, page 13) carried a report on the reduction in average grant length being implemented by the National Institutes of General Medical Science in response to the Congressional request that the National Institutes of Health develop a long-range plan for cost containment. In this same article, it was also reported that the institute is also eliminating the practice of downward negotiations, a euphemism that NIH had employed over the past several years to describe its yearly practice of unilaterally reducing the annual funding level of approved and funded continuing grants in order to accommodate annual fiscal budget constraints. Indeed, over the past several years these reductions have averaged 10 to 12% of the amounts originally approved and recommended by the relevant NIH institute and carried on the original grant award statement.

Unfortunately, while NIH has discontinued use of the term "downward negotiations," it has not abandoned the practice of reducing grant awards. Only the manner in which these reductions are presented has changed. NIH now proposes to limit annual increases in noncompeting awards to an average of 3 to 4%, using the actual fiscal-year 1990 award level as the new base. Since in almost all cases the 1990 award level already included a downward negotiation of 10 to 12%, the result of this announced policy change will be to make the previous administrative reductions permanent. The formulation of the plan is misleading as well as disingenuous in that it is intended to convey the impression to Congress and the scientific community that NIH has abandoned downward negotiations while doing exactly the opposite. Every principal investigator will still receive a net 10 to 12% reduction in 1991 and future years below the previously approved and recommended levels. If NIH feels compelled by the competing demands put on its budget to cut funded research grants across the board, it should state this clearly to the scientific community and to Congress. The appearance of articles such as that in C&EN only illustrates the early success it has had in distracting attention from what it is actually doing.

David E. Cane
Professor of Chemistry
Brown University

Corrections

- Nov. 26, 1990, page 54: The reference to the review of Paul Brodeur's book at the end of James Jauchem's letter to the editor should be Ashley, J. R., *IEEE Antennas & Propagation Soc. Mag.*, **32(2)**, 45 (1990).
- March 4, page 43: 3M Scotchweld AF 191 epoxy film adhesive has a service temperature up to 400 °F, not 300 °F.

Top 50 Chemicals Production Resumed Growth Last Year

Output increased 2% to an all-time high of 626 billion lb; organics production moved up 2.7%, while that of inorganics rose 1.6% from 1989

Marc S. Reisch,
C&EN Northeast News Bureau

Although the economic slowdown of 1990 hurt production of U.S. chemical industry customers such as auto makers and housing and office builders, U.S. chemical production itself actually recovered from a significant slowdown in 1989.

According to C&EN's annual ranking of the 50 largest volume chemical products, total production in that group increased a modest 2% in 1990 from 1989. Production reached an all-time high of 626 billion lb, significantly better than the 613 billion lb in 1989, which was just 0.2% more than in 1988.

According to the Federal Reserve Board, chemical production perked along with a seasonally adjusted 3.1% rise between the fourth quarter of 1989 and the fourth quarter of 1990. By comparison, the Federal Reserve Board figures show that between the fourth quarter of 1988 and the fourth quarter of 1989, chemical production increased 2.2% despite the increases in industry capacity brought on during that year.

Most of the increased production in 1990 took place during the first and second quarters prior to the Iraqi invasion of Kuwait, when chemical production increased at a seasonally adjusted 4.8% in the first quarter of 1990 and 4.4% in the second quarter. However, following the invasion, chemical production, reacting to increases in energy and feedstock prices at the time, dropped off. Chemical production increased at a seasonally adjusted rate of 2.9% in the third quarter of 1990 and dropped back further to a 0.3% increase in the fourth quarter.

To judge by the depressed Federal Reserve statistics regarding production levels for the transportation, construction, appliance, carpeting, and furniture industries during 1990, all major users of chemical products, domestic demand could not account for chemical production

About the Top 50 list of chemical products

Government data, trade association figures, and industry estimates, all go into preparing C&EN's annual list of the Top 50 chemical products, ranked by production volume. The federal government is relied upon most heavily, but when government figures are not available, other sources, primarily trade associations, are used. Industry sources and C&EN estimates are used only when other data are lacking.

Government data are not always accurate—they are only as good as the information that individual companies report. But they are an objective measure of production extending back many years. Therefore, relatively accurate indications of growth can be made on a consistent basis.

At this time of year, C&EN has access only to preliminary reports of production for 1990. When the government and trade associations issue their final reports, the outcome can be changed, sometimes dramatically. As a result, the production figures for earlier years that appear in the table on page 14 are different in some cases from those published in last year's Top 50 article. The final reports also can affect the rankings of chemicals. For the table on page 14, the 1989 ranking of 11 chemicals is different from last year's listing (C&EN, April 9, 1990, page 11).

The list itself covers production figures for the U.S. and includes chemicals produced for export. Candidates for the list include all basic, intermediate, and chemically homogeneous finished products. These range from the chemical building blocks like ethylene and propylene to downstream products like vinyl acetate and ethylene glycol.

The roster includes basic inorganic chemicals but does not include what C&EN considers to be minerals, such as salt, gypsum, and sulfur. Lime is included because it is processed and has many chemical and industrial applications. Refractory (dead burned) dolomite is excluded in lime production.

In the organics list, such petrochemical feedstocks as ethane, butane, and propane are excluded arbitrarily because they are considered to be products of oil companies and because they have many nonchemical uses.

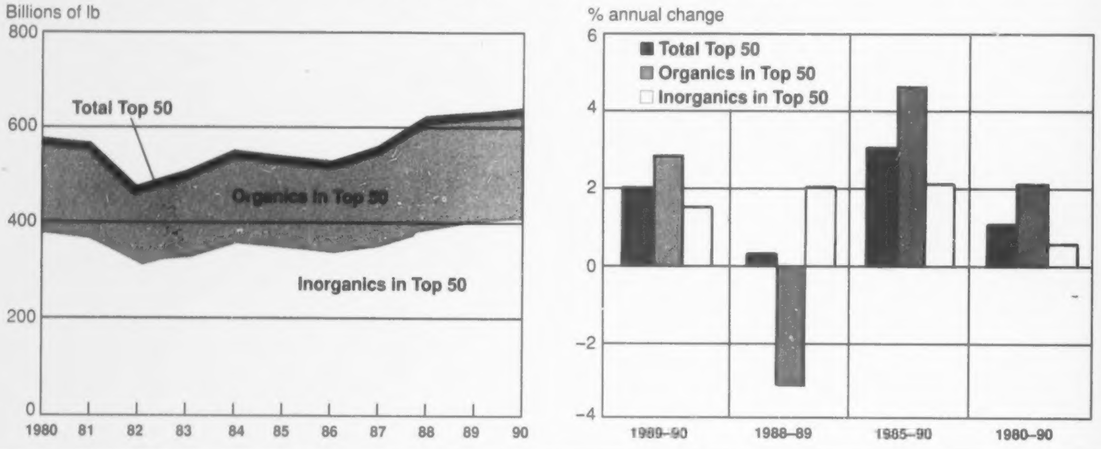
There are other gray areas besides lime and petrochemical feedstocks. For example, the basic aromatics—benzene, toluene, and xylene—are included.

Production figures are published by the government in a variety of units—pounds, tons, cubic feet, gallons, metric tons, and, most recently, kilograms and liters. Where the latter two units are used, they have been converted, where appropriate, into the common units that the government and industry have historically used as points of reference. To provide an accurate ranking and to make comparison of production volumes easier, C&EN lists production not only in common units, but converted to pounds.

Top 50 chemical production totaled about 626 billion lb last year

Rank			Billions of lb		Common units[b]		Average annual growth			
1990	1989[a]		1990	1989	1990	1989	1989-90	1988-89	1985-90	1980-90
1	1	**Sulfuric acid**	88.56	86.60	44,281 tt	43,301 tt	2.3%	2.8%	2.1%	0 %
2	2	**Nitrogen**	57.32	53.91	791 bcf	744 bcf	6.3	3.0	3.8	5.1
3	3	**Oxygen**	38.99	37.42	471 bcf	452 bcf	4.2	0	3.7	0.9
4	4	**Ethylene**	37.48	34.95	37,480 mp	34,953 mp	7.2	−6.0	4.7	2.7
5	5	**Lime**[c]	34.80	34.36	17,400 tt	17,178 tt	1.3	0.7	1.9	−0.9
6	6	**Ammonia**	33.92	32.72	16,958 tt	16,362 tt	3.6	−2.7	−0.4	−1.5
7	7	**Phosphoric acid**	24.35	23.47	12,175 tt	11,735 tt	3.7	0.5	3.0	1.2
8	9	**Sodium hydroxide**	23.38	20.98	11,688 tt	10,492 tt	11.4	−0.3	1.4	0.1
9	10	**Propylene**	22.12	20.23	22,117 mp	20,229 mp	9.3	−4.7	8.2	4.9
10	8	**Chlorine**	21.88	22.83	10,942 tt	11,413 tt	−4.1	1.4	1.0	−0.4
11	11	**Sodium carbonate**[d]	19.85	19.83	9,925 tt	9,915 tt	0.1	2.9	3.1	1.8
12	13	**Urea**[e]	15.81	15.93	7,905 tt	7,963 tt	−0.7	0.6	3.4	0.1
13	12	**Nitric acid**	15.50	16.70	7,749 tt	8,349 tt	−7.2	4.5	1.0	−1.7
14	14	**Ammonium nitrate**[f]	14.21	15.74	7,107 tt	7,871 tt	−9.7	4.9	1.0	−2.5
15	15	**Ethylene dichloride**	13.30	13.68	13,301 mp	13,675 mp	−2.7	5.0	1.9	1.8
16	16	**Benzene**	11.86	11.67	1,610 mg	1,585 mg	1.6	−0.5	4.8	−2.2
17	17	**Carbon dioxide**[g]	10.98	10.68	5,491 tt	5,339 tt	2.8	5.6	1.9	6.2
18	18	**Vinyl chloride**	10.65	9.62	10,652 mp	9,618 mp	10.8	6.2	2.4	5.1
19	19	**Ethylbenzene**	8.99	9.22	8,988 mp	9,223 mp	−2.5	−7.1	4.0	1.6
20	21	**Styrene**	8.02	8.13	8,018 mp	8,129 mp	−1.4	−9.5	1.0	1.6
21	22	**Methanol**	7.99	7.14	7,987 mp	7,139 mp	11.9	−12.3	9.8	1.1
22	20	**Terephthalic acid**[h]	7.69	8.31	7,692 mp	8,309 mp	−7.4	−18.8	3.5	2.4
23	23	**Formaldehyde**[i]	6.41	6.37	6,413 mp	6,370 mp	0.7	1.4	2.7	1.4
24	30	**Methyl *tert*-butyl ether**[j]	6.30	4.98	6,302 mp	4,976 mp	26.6	−12.4	27.2	na
25	25	**Toluene**[k]	6.10	5.84	841 mg	805 mg	4.5	−8.0	3.8	−1.9
26	26	**Xylene**	5.70	5.80	791 mg	805 mg	−1.7	5.8	1.4	−1.4
27	29	**Ethylene oxide**	5.58	5.32	5,581 mp	5,322 mp	4.9	−10.6	0.6	0.7
28	28	***p*-Xylene**	5.20	5.49	5,201 mp	5,494 mp	−5.3	−1.9	1.7	2.1
29	27	**Ethylene glycol**	5.03	5.50	5,028 mp	5,499 mp	−8.6	−0.3	3.8	1.4
30	31	**Ammonium sulfate**	4.99	4.69	2,495 tt	2,347 tt	6.3	0.6	3.6	1.6
31	24	**Hydrochloric acid**	4.68	6.35	2,341 tt	3,177 tt	−26.3	20.3	−3.5	−2.1
32	32	**Cumene**	4.31	4.54	4,312 mp	4,535 mp	−4.9	1.8	5.2	2.2
33	34	**Acetic acid**	3.76	3.83	3,756 mp	3,826 mp	−1.8	21.1	5.3	2.4
34	35	**Potash**[l]	3.62	3.52	1,640 tmt	1,595 tmt	2.8	4.9	4.8	−3.1
35	33	**Phenol**[m]	3.51	3.89	3,512 mp	3,893 mp	−9.8	9.3	4.8	3.2
36	36	**Propylene oxide**	3.20	3.20	3,200 mp	3,200 mp	0	2.9	5.9	6.1
37	37	**Butadiene**[n]	3.16	3.09	3,156 mp	3,094 mp	2.0	−2.4	6.2	1.2
38	39	**Acrylonitrile**	3.03	2.61	3,029 mp	2,608 mp	16.1	0	5.2	5.2
39	38	**Carbon black**	2.87	2.91	2,868 mp	2,913 mp	−1.5	−0.1	2.2	1.2
40	42	**Vinyl acetate**	2.55	2.47	2,546 mp	2,470 mp	3.1	−3.6	3.8	2.8
41	43	**Cyclohexane**	2.47	2.39	2,468 mp	2,389 mp	3.3	4.0	8.3	2.3
42	41	**Aluminum sulfate**	2.42	2.49	1,208 tt	1,244 tt	−2.9	1.0	−1.0	−0.6
43	40	**Acetone**	2.22	2.50	2,221 mp	2,497 mp	−11.1	8.4	4.4	0.7
44	44	**Titanium dioxide**	2.16	2.20	1,079 tt	1,101 tt	−2.0	7.7	4.6	4.2
45	46	**Sodium silicate**	1.76	1.67	878 tt	834 tt	5.3	2.7	4.9	0.9
46	47	**Adipic acid**	1.64	1.64	1,640 mp	1,640 mp	0	2.5	2.5	1.1
47	48	**Sodium sulfate**[o]	1.47	1.51	733 tt	755 tt	−2.9	−7.6	−2.4	−4.3
48	45	**Calcium chloride**[p]	1.38	1.92	690 tt	962 tt	−28.3	32.0	−2.9	−3.5
48	49	**Isopropyl alcohol**	1.38	1.43	1,380 mp	1,432 mp	−3.6	3.1	2.2	−2.8
48	50	**Caprolactam**	1.38	1.31	1,380 mp	1,312 mp	5.2	4.0	5.0	4.3
TOTAL ORGANICS			216.82	211.07			2.7%	−3.0%	4.6%	2.1%
TOTAL INORGANICS			409.07	402.51			1.6%	2.0%	2.1%	0.5%
GRAND TOTAL			625.89	613.58			2.0%	0.2%	2.9%	1.0%

a Revised. **b** **tt** = thousands of tons, **bcf** = billions of cubic feet, **mp** = millions of pounds, **mg** = millions of gallons, **tmt** = thousands of metric tons. **c** Except refractory dolomite. **d** Natural and synthetic. **e** 100% basis. **f** Original solution. **g** Liquid and solid only. **h** Includes both acid and ester without double counting. **i** 37% by weight. **j** Production data for earlier years unavailable. **k** All grades. **l** K_2O basis. **m** Synthetic only. **n** Rubber grade. **o** High and low purity. **p** Solid and liquid. **na** = not available.



Production of Top 50 chemicals grows modestly to hit record high

increases. And while it is true that automobile manufacturers are using more plastics and chemical adhesives per vehicle, the use of chemical products still has not increased so much that it would so significantly outstrip auto and truck production, which declined 11% between the fourth quarter of 1989 and the fourth quarter of 1990.

Just like 1989, significant exports of U.S.-produced chemicals can account in large measure for how well the U.S. chemical industry has done by comparison with other major industries. U.S. chemical exports were $37.6 billion in 1989, according to the U.S. Bureau of the Census. Based in part on government data along with industry projections, the Chemical Manufacturers Association estimates that U.S. exports rose again in 1990 to $38 billion.

The trend of growing U.S. chemical exports just may continue to sustain production growth in 1991. Chevron, Exxon Chemical, and Mitsubishi plan to expand an ethylene import terminal allowing the partners to export product from Chevron U.S.A.'s Galena Park Terminal on the Houston Ship Channel (C&EN, March 25, page 7). When it comes on line in the third quarter of 1991, the facility will be able to export up to 400,000 tons annually.

Among the largest volume chemicals produced in the U.S., sulfuric acid remains at the top with total production of 88.6 billion lb, up 2.3% from 1989. The increase in production was not quite so good as the 2.8% rise the previous year. For 1990, nitrogen continues to rank a distant number two, with production at 57.3 billion lb, up 6.3% from 1989. Nitrogen production grew at a much faster pace than it did in 1989 when output was up only 3%.

Of the Top 50, the 29 organic chemicals accounted for some 35% of total production, compared with 34% in 1989. The combined organics production increased 2.7% in 1990 from the previous year, after a 3% decline in 1989. Over the five-year period 1985-90, combined production of organic chemicals among the Top 50 increased an average of 4.6% a year. But historically, their output has grown at a slower pace. Between 1980 and 1990, combined output of organic chemicals among the Top 50 grew at a compound annual rate of 2.1% a year.

While organic chemical production rebounded in 1990, inorganic chemical production slowed compared with the previous year. Combined output of inorganics on the list rose only 1.6% from the previous year, following a 2% increase in 1989. Over the five-year period from 1985 to 1990, combined production of inorganic chemicals grew at an average annual rate of 2.1% a year. Like the organics group, inorganics production historically has grown at a slower pace: 0.5% between 1980 and 1990.

For organic chemicals, 1990 growth was led by methyl tert-butylether (MTBE), production of which rose 27% from 1989 to 6.3 billion lb. As a result, MTBE moved to 24th place on the 1990 list from 30th place on the 1989 list. Acrylonitrile production also grew at a double-digit pace, up 16% in 1990 to 3 billion lb. Acrylonitrile's strong growth moved it to 38th place on the Top 50 list from 39th place the previous year. Vinyl chloride production grew 11% from 1989 to 10.7 billion lb, but its growth was not sufficient to improve its ranking from 18th place.

Only one organic chemical registered a double-digit decline in 1990 production: Acetone output dipped 11% to 2.2 billion lb. The decrease moved acetone down to 43rd place from 40th place the previous year.

For inorganic chemicals, 11 of the 21 on the Top 50 list posted production increases, led by sodium hydroxide with 11% to reach 23.4 billion lb in 1990. The gain pushed sodium hydroxide to eighth place from ninth in the 1989 ranking.

Two inorganics—nitrogen and ammonium sulfate—tied for the next largest gain of 6.3%. Nitrogen production rose to 57.3 billion lb, keeping it in second place in the ranking; and ammonium sulfate production rose to 5 billion lb, moving it up to 30th place from 31st in 1989.

Sodium silicate also did well, with production rising 5.3% from 1989 to 1.8 billion lb, boosting it to 45th place from 46th the previous year.

Despite these gains, production declined for almost half of the inorganics, some declining significantly. The biggest underachiever was calcium chloride, production of which is estimated to have declined 28% in 1990. Calcium chloride thus slipped to 48th place from 45th in 1989. The large swing in calcium chloride production may not be an entirely accurate picture because such a large part of the data on which the Bureau of Mines depends is based on an estimate. A statistician for the Bureau of Mines notes that despite the swings in production reports, the figures reported were the best estimates the government could make because it could not get a good figure from Dow Chemical and thus had to rely on industry estimates.

Also showing a double-digit decline in production was hydrochloric acid, with output dropping 26% in 1990 to 4.7 billion lb. In 1989, hydrochloric acid production rose 20%.

All in all, of the Top 50 chemicals, production of 26 of them increased in 1990. By contrast production of 30 increased in 1989. Total production of the Top 50 chemicals, at 626 billion lb, was 35% higher than the decade low of 464 billion lb registered in 1982.

For the Top 50 group, composite output increased at a compound annual rate of 2.9% between 1985 and 1990. Long-term growth for the group as a whole was at an even slower pace. Between 1980 and 1990, Top 50 production grew at an average annual rate of 1%.

Looking at growth over the past 10 years, 34 of the Top 50 chemicals have recorded overall production increases. The best long-term growth performer has been carbon dioxide, output of which grew at an annual compound rate of 6.2% during the period. Propylene oxide turned in the next best performance with long-term growth of 6.1%. Other chemicals with sizable annual growth rates were acrylonitrile, up 5.2%; nitrogen and vinyl chloride, both up 5.1%; and propylene, up 4.9%. Sodium sulfate registered the largest decline over the past 10 years, with output falling at a compound annual rate of 4.3%. □

Plastics lead polymer output recovery

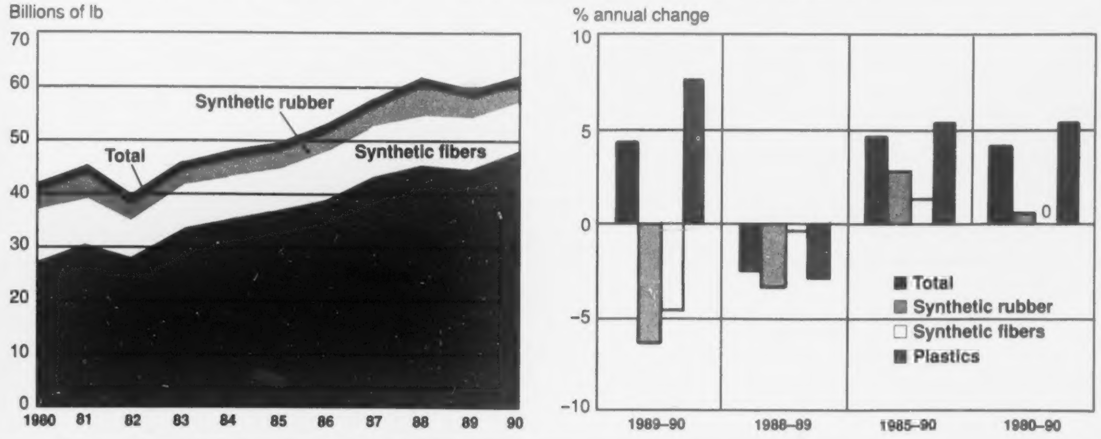
Overall U.S. production of commercial polymers, including plastics, synthetic fibers, and synthetic rubber, increased 4.3% in 1990 following a 2.3% decline in 1989. As a result, output, which faltered in 1989 following seven years of growth, resumed growth. Total 1990 polymer output reached 61.6 billion lb, a new record, topping the 60.5 billion lb record set in 1988.

Plastics production increased at such a fast rate, it led a recovery for a category that otherwise sustained production declines. As a group, plastics account for more than three quarters of the polymer category's production total. The 7.3% production rise for plastics helped overcome the 6.5% decline in fibers and 4.6% decline in synthetic rubber production in 1990. The plastics group recovered from a 2.5% production decline in 1989.

Production of thermoplastic resins grew at a rate of 8.6% in 1990 following a decline of 2.5% in 1989. Thermosetting resins, off 0.6%, performed better in 1990 compared with 1989, when their production declined 2.8%.

Among the thermoplastics, low-density polyethylene production grew at an annual rate of 15.3% in 1990, recovering nicely from a 6.8% drop in 1989 compared with the previous year. Polypropylene turned in the next best performance in 1990, with output up 14.9% in 1990 compared with a 0.5% decline in 1989. Production of polyvinyl chloride and copolymers was up 7.2%, and output

Plastics output rose, but that of synthetic fiber, rubber declined in 1990



Total polymer production pushed past 61 billion lb in 1990

	Billions of lb		Common units					Average annual growth			
	1990	1989	1990	1989	1988	1985	1980	1989–90	1988–89	1985–90	1980–90
PLASTICS (millions of lb)											
Thermosetting resins	**6.36**	**6.41**	**6,364**	**6,405**	**6,588**	**5,631**	**4,093**	**−0.6%**	**−2.8%**	**2.5%**	**4.5%**
Phenol and other tar acid resins	2.95	2.88	2,946	2,879	3,066	2,621	1,499	2.3	−6.1	2.4	7.0
Urea resins	1.50	1.48	1,496	1,476	1,425	1,210	1,165	1.4	3.6	4.3	2.5
Polyesters (unsaturated)	1.22	1.32	1,221	1,319	1,404	1,223	947	−7.4	−6.1	0	2.6
Epoxies (unmodified)	0.50	0.51	499	509	486	385	315	−2.0	4.7	5.3	4.7
Melamine resins	0.20	0.22	202	222	207	192	167	−9.0	7.2	1.0	1.9
Thermoplastic resins	**41.93**	**38.62**	**41,928**	**38,617**	**39,608**	**31,525**	**24,335**	**8.6%**	**−2.5%**	**5.9%**	**5.6%**
Low-density polyethylene	11.18	9.70	11,176	9,695	10,397	8,889	7,291	15.3	−6.8	4.7	4.4
PVC and copolymers	9.09	8.48	9,088	8,478	8,350	6,772	5,470	7.2	1.5	6.1	5.2
High-density polyethylene	8.33	8.10	8,334	8,102	8,400	6,671	4,405	2.9	−3.5	4.6	6.6
Polystyrene[a]	5.01	5.10	5,012	5,104	5,187	4,054	3,521	−1.8	−1.6	4.3	3.6
Polypropylene	8.32	7.24	8,318	7,238	7,274	5,139	3,648	14.9	−0.5	10.1	8.6
TOTAL[b]	**48.29**	**45.02**	**48,292**	**45,022**	**46,196**	**37,156**	**28,428**	**7.3%**	**−2.5%**	**5.4%**	**5.4%**
SYNTHETIC FIBERS (millions of lb)											
Cellulosics	**0.50**	**0.58**	**502**	**580**	**614**	**558**	**806**	**−13.4%**	**−5.5%**	**−2.1%**	**−4.6%**
Rayon[c]	0.30	0.36	296	363	400	353	490	−18.5	−9.3	−3.5	−4.9
Acetate[d]	0.21	0.22	206	217	214	205	316	−5.1	1.4	0.1	−4.2
Noncellulosics[b]	**8.18**	**8.52**	**8,175**	**8,515**	**8,526**	**7,564**	**7,874**	**−4.0%**	**−0.1%**	**1.6%**	**0.4%**
Polyester	3.19	3.59	3,193	3,594	3,680	3,341	3,989	−11.2	−2.3	−0.9	−2.2
Nylon[e]	2.66	2.74	2,661	2,740	2,670	2,343	2,358	−2.9	2.6	2.6	1.2
Olefin[f]	1.82	1.64	1,815	1,639	1,588	1,249	748	10.7	3.2	7.8	9.3
Acrylic[g]	0.51	0.54	506	542	588	631	779	−6.6	−7.8	−4.3	−4.2
TOTAL[b]	**8.68**	**9.10**	**8,677**	**9,095**	**9,140**	**8,122**	**8,680**	**−4.6%**	**−0.5%**	**1.3%**	**0 %**
SYNTHETIC RUBBER (thousands of metric tons)											
Styrene-butadiene[h]	1.88	1.93	853	874	909	735	1,074	−2.4	−3.9	3.0	−2.3
Polybutadiene	0.89	0.91	403	411	407	330	311	−1.9	1.0	4.1	2.6
Ethylene-propylene	0.56	0.57	256	260	263	215	144	−1.5	−1.1	3.6	5.9
Nitrile	0.12	0.15	56	69	76	53	63	−18.8	−9.2	1.1	−1.2
Other[i]	1.20	1.43	546	648	679	505	423	−15.7	−4.6	1.6	2.6
TOTAL[b]	**4.66**	**4.99**	**2,114**	**2,262**	**2,334**	**1,838**	**2,015**	**−6.5%**	**−3.1%**	**2.8%**	**0.5%**

a No longer includes acrylonitrile-butadiene-styrene, or styrene acrylonitrile resins; historical data are restated. b Totals are for those products listed and may not add because of rounding. c Based on C&EN estimates. d Includes diacetate and triacetate yarn, but does not include cigarette tow. Beginning with 1985, includes rayon yarn. e Excludes aramid after 1982. f Includes olefin film, olefin fiber, spun-bonded polypropylene, and vinyon. g Includes modacrylic. h Excludes high-styrene latex. i Beginning with 1985, includes neoprene; historical data are restated. Also includes butyl; polyisoprene; chlorosulfonated polyethylene; polyisobutylene; and acrylo, fluoro, and silicone elastomers. **Sources:** Society of the Plastics Industry, Fiber Economics Bureau, Rubber Manufacturers Association

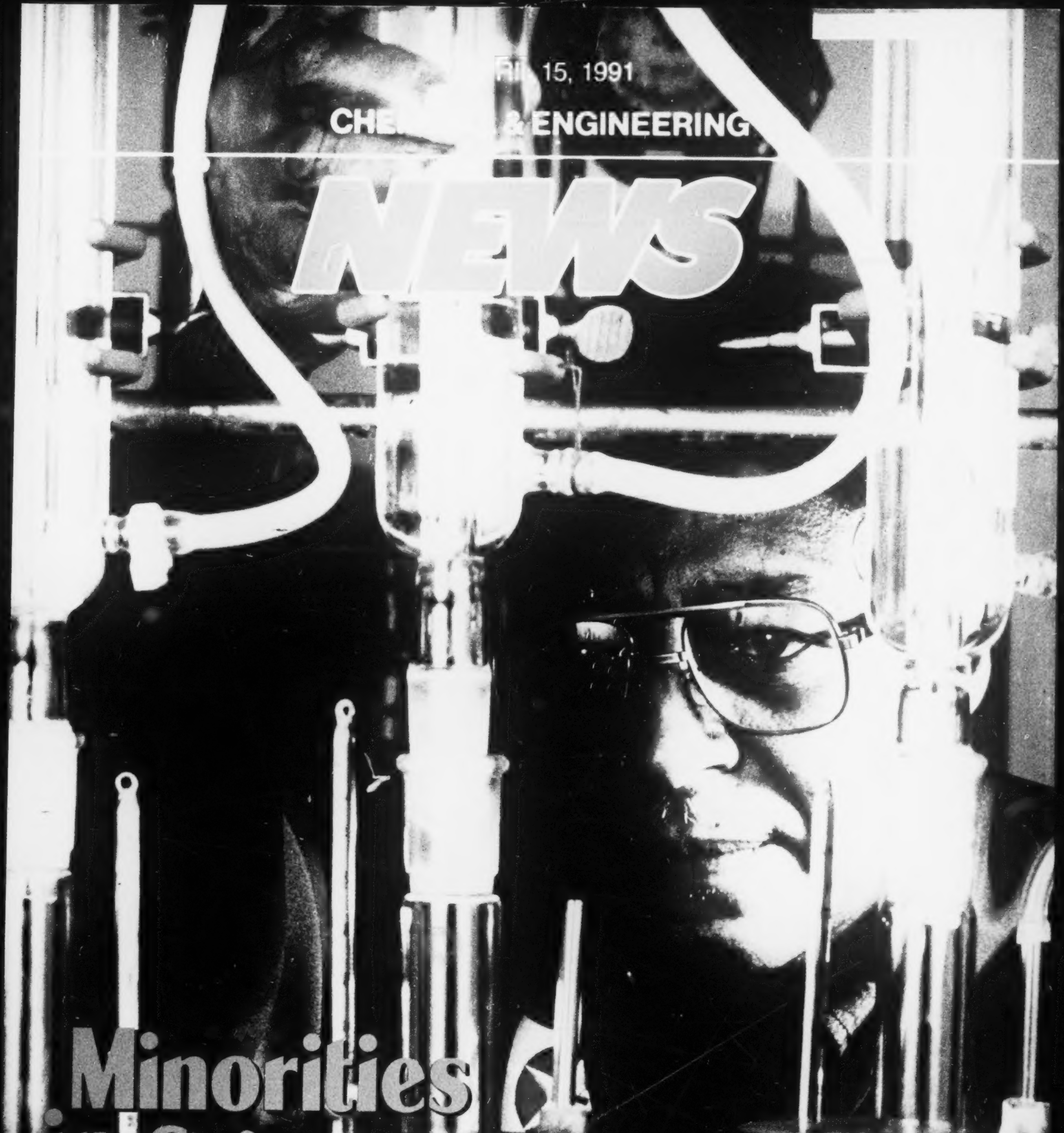
of high-density polyethylene rose 2.9% in 1990, compared with a 1.5% rise and a 1.6% decline, respectively, in 1989. Only polystyrene registered a production decline among the thermoplastics in 1990, down 1.8% after a 1.6% decline in 1989.

In the thermosetting resins category, phenol and other tar acid resins staged a modest growth recovery to 2.3% in 1990 following a 6.1% decline in 1989. Urea resins output rose only 1.4% in 1990 compared with a 3.6% rise in 1989. Other thermosetting resins fared poorly in 1990. Melamine resins, which showed good growth in 1989, led the decline in 1990. Their production was off 9% in 1990 compared with a 7.2% gain in 1989. Unsaturated polyesters output declined 7.4% in 1990 and unmodified epoxies output declined 2%. In 1989, polyester production declined 6.1% and epoxies rose 4.7%.

The synthetic rubber segment's decline accelerated in 1990. Output dropped 6.5% in 1990 compared with a 3.1% decline in 1989. Production totaled 4.7 billion lb in 1990 compared with 5 billion lb in 1989. None of the synthetic rubber categories registered production increases in 1990. The best performer, if indeed it could be called such, was ethylene-propylene type polymers, production of which declined 1.5% in 1990 compared with a 1.1% decline in 1989. Polybutadiene production was down 1.9%, following a 1.0% decline in 1989, while styrene-butadiene was off 2.4% after a 3.9% decline in 1989. Nitrile rubber showed the largest decline in 1990, down 19%, while the category listed as other, and including neoprene, butyl, polyisoprene and other rubbers, declined 16%.

While synthetic fiber output declined marginally in 1989 from 1988, the economic slowdown of 1990 had a severe impact on the category. Overall fiber output declined 4.6% in 1990. While imported textiles continued to put pressure on domestic textile output and fiber use, consumer preference for cotton also had an impact on synthetic fiber production. Among the noncellulosics, only olefin output appeared to do well, up 11% in 1990.

Marc Reisch



ril 15, 1991

CHE & ENGINEERING

NEWS

Minorities in Science

Efforts are growing to increase participation of historically underrepresented groups

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CHEMICAL & ENGINEERING
NEWS
APRIL 15, 1991

Volume 69, Number 15
CENEAR 69 (15) 1–56
ISSN 0009-2347

News of the Week

- **Key new findings in C_{60} chemistry have been made, including confirmation from x-ray crystallography that a fullerene is shaped like a soccer ball.** Page 4
- **NAS report urges strong action to reduce greenhouse gas emissions to the atmosphere despite continuing uncertainties about the threat of global warming.** Page 5
- **Many questions surround destruction of Iraq's chemical weapons capabilities, called for in UN cease-fire resolution.** Page 5
- **Destruction of Earth's protective ozone layer apparently is speeding up, ongoing NASA studies of satellite data indicate.** Page 6

Cover: Photo courtesy of Texaco Inc.

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Business

New CEFIC head, Baron Daniel Janssen, discusses environmental concerns, other issues confronting the European chemical industry organization in the next few years. **Page 9**

Government

Agent orange has had little if any health impact on Vietnam veterans, two new studies find. **Page 12**

Government policies have led to farming that harms environment, make sustainable practices less profitable, charges a report by the World Resources Institute. **Page 13**

Science/Technology

Rehabilitation of oil-soaked waterfowl is focus of effort by chemists from Du Pont and Tri-State Bird Rescue & Research Inc. **Page 15**

Ceramics from particles less than 50 nm in diameter are goal of Nanophase Technologies Corp., using Argonne techniques. **Page 15**

Low-cost precollege chemistry kit that simulates diffraction is offered by University of Wisconsin. **Page 16**

Priestley Medal Address

Caltech's Harry B. Gray speaks of chemical research and education and the joy and synergism of research and teaching. **Page 17**

Books

"Peerless Science: Peer Review and U.S. Science Policy" explores the peer review process, its shortcomings, benefits, and relation to science policy. **Page 36**

Special Report

Increasing the participation of long-underrepresented minorities in science is the focus of an array of public- and private-sector initiatives. Page 20

Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
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Subscription Rates 1991. Printed editions: nonmembers U.S. 1 yr. $95, 2 yr. $171; outside U.S. 1 yr. $131, 2 yr. $243. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $12. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Expenditure clarification

Du Pont seeks to clarify its R&D expenditures reported in the table on page 13 of the article, "Chemical Industry R&D Spending To Increase Modestly" (C&EN, Jan. 21, page 11).

To compare Du Pont's 1991 R&D expenditures estimate with 1990 actual, you must exclude pharmaceuticals-related research that was in Du Pont in 1990 but transferred in 1991 to the new Du Pont Merck Pharmaceuticals, a separate company formed on Jan. 1.

Consequently, the restated 1990 figure without pharmaceuticals is $1.15 billion and the 1991 estimate is $1.22 billion, an increase of about 6%. (If pharmaceuticals-related research had remained in Du Pont in 1991, the total R&D increase would have risen at a similar percentage.)

John L. Stowell
Du Pont, Wilmington, Del.

ACS member involvement

I read all of new President Allen Heininger's message (C&EN, Jan. 7, page 2) quite carefully. I found a great deal to agree with, particularly in the field of education. But when he suggests streamlining the governance of ACS, I departed sharply.

He seems to be complaining that there are a large number of committees, subcommittees, boards, etc., as though that is something inappropriate. Perhaps it would be, for a business, but ACS is not a business. It is a 501 C3 membership organization. A membership organization serves its members best when there is extensive membership participation. This is one way to ensure it. It also helps us to attract new members and retain existing members.

If one looks at the first page of the ACS Directory of Governance (the "Yellow Book") one sees right at the top of the diagram of "Governing Bodies of the ACS" a box that says, "Membership of the ACS"—indicating that the members are the boss. The effective participation of so many ACS members in its governance constitutes a strength. It is not a weakness. After all, the first responsibility of ACS is to its own members and this is one way to ensure it.

Not that one shouldn't always be looking for better and more efficient ways of taking care of the society's affairs, and of making it more representative and more constructive. The society does have a disproportionate number of academics in its governance. It does not have a proportionate share of bachelor's and master's degrees in its ruling circles. This is something that has to be constantly kept in mind for correction, as Heininger acknowledges.

But the members are not well served if their professional and economic health is not adequately addressed. One of past-president Paul Gassman's major concerns seemed to have been to reduce the influence of the council in these matters by blending the committees of Professional Relations, Economic Status, and Professional & Member Relations into a supercommittee—in which councilors would have less influence—and to eliminate PROPPACC. I think this would be unwise. These are precisely the committees that are most vigilant in representing the interests of the vast majority of our members and are so perceived to be. Not that these committees are immune from error, but who is? Eliminating the council would work against some of the goals that our new president says he's for, to improve our concern for nondoctorate and industrial members. We should retain these committees and work to get more non-Ph.D.s to become councilors so they could become members of committees. Also, presidents-elect, who are responsible for appointments, should be sensitive to the need for such action.

I foresee rather difficult times for chemists in the next few years as the recession deepens and the new board-favored immigration laws, which will allow a flood of foreign chemists into the country, come into effect in 1993. So I feel this is a particularly poor time to weaken member involvement in ACS.

Alan C. Nixon
Berkeley, Calif.

Antiwar protests

The article on antiwar protests by scientists (C&EN, Jan. 21, page 5) cannot be left to suggest that all, or even many, scientists are against the allied actions against Saddam Hussein in the Persian Gulf War. While the motives of scientists like Linus Pauling and Dudley Herschback are not in question, their actions reveal a startling naiveté about humanity.

The statement that "sanctions and a sustained diplomatic siege" could produce results was discounted uniformly as it was realized that Hussein and his army would retain whatever was left in Iraq and only civilians would suffer from shortages. Six months of sanctions produced no effects, and the routes for bridging the trade embargoes became clearly uncontrollable. These arguments

MINORITIES IN SCIENCE

Growing effort aims to increase participation of historically underrepresented groups

Rebecca L. Rawls, C&EN Washington

There are 54 million blacks, Hispanics, American Indians, and Alaskan natives living in the U.S., 22% of the total population. Members of these ethnic groups are generally poorer, less well educated, and much less likely to be scientists or engineers than are people from the other 78% of the population. In 1988, only 4.4% of the 4.5 million people employed as natural scientists or engineers in the U.S. were members of these minority groups.

Yet these groups are also among the fastest growing segments of the U.S. population. Blacks and Hispanics, who accounted for 25% of school-age children in 1988, will represent 47% of that group by the year 2020. For the remainder of the decade, 42% of the new entrants into the labor force are expected to be minorities, according to estimates made by the Department of Labor.

At the same time, science and engineering careers are becoming much less attractive to middle-class white males, the group that traditionally has produced most of our scientists and engineers. The National Science Foundation estimates that by the year 2010, the U.S. could suffer a shortfall of as many as 560,000 science and engineering professionals, based on the levels that would have been produced had graduation rates in these fields remained at their 1984–86 levels.

These forces have come together to produce what some observers are calling a window of opportunity for efforts to increase minority participation in the sciences and engineering. A major new federal initiative spearheaded by NSF has been coupled with increased efforts from industry consortia and professional societies and with greater funding for programs already in place that have proven records of success. All these activities point to a new climate for attracting minorities to science careers.

The rationale for this effort is straightforward. As Erich Bloch, then director of NSF, put it last fall, "Our world is increasingly competitive, and our economy increasingly depends on scientific and technical excellence. That excellence, in turn, depends on people—people with education and skills in every area of science and technology.

"More and more, a focus on people means a focus on minorities, because minorities are a resource we have not fully used. Minorities have not been drawn to science and engineering in sufficient numbers, and earn far fewer advanced degrees in science and engineering than their relative numbers in the population would indicate."

The underrepresentation of certain ethnic groups in science and engineering has always been a matter of concern to some, because it implies a lack of equal opportunity for all Americans that is contrary to the ideals of a democratic society. And a number of organizations—notably the National Institutes of Health and calculate the electronic structures of large molecules and in some cases even their reaction pathways. Theory has reached the point where chemists can actually predict many aspects of molecular structure and reactivity. During the course of my career I have seen theoretical chemistry emerge as a major subfield of chemistry.

Experimental chemical physics has been revolutionized by lasers. Lasers allow us to examine chemical reactions that occur very rapidly, reactions that only take trillionths or even fractions of trillionths of seconds. Thanks to lasers, it is now possible literally to see the primary events of chemical reactions, the very first movements of atoms as they separate from molecules. This sort of fundamental understanding of the reactions of molecules is truly phenomenal.

The work of inorganic and organic chemists has been changed completely by advances in synthesis technology. Our ability to design and synthesize whole new classes of molecules will lead to dramatic breakthroughs in medical science. This ability also will provide the materials that will be required for molecular memory. In discussing this area, Richard Feynman predicted that molecular memory will allow us to increase the speed of today's supercomputers a millionfold or even more! I like the idea that chemistry will provide the super-supercomputers of the future.

The importance of fundamental research in chemistry will be highlighted in the 1990s by responses to a multitude of environmental issues. Chemists will be called upon time and time again to replace dangerous chemicals with safer ones. Research that may lead to the replacement of hydrofluoric acid by less toxic acids (solid superacids?) and chlorofluorocarbons by molecules that are less threatening to stratospheric ozone is being done because of very real concerns about the environment. And more and more energy research will be directed toward the production of fuels that can reduce the risk of global warming.

We will see renewed research initiatives in artificial photosynthesis. It is our hope that we can make molecules that will affect the direct conversion of sunlight and very abundant raw materials directly into high-energy chemicals, directly into fuels that we can use to heat homes, make electricity, run cars, and so forth. Those of us who work in this field hope that by the end of the decade some of this research will have reached an advanced stage of development and will have begun to have some impact.

A main goal of artificial photosynthesis is to use solar photons to split water to hydrogen and oxygen. Hydrogen is very energy-rich; and it is a clean-burning fuel, giving only water as the product. Pollution problems would be reduced tremendously if we burned hy-

Continued on page 39

Solutions.

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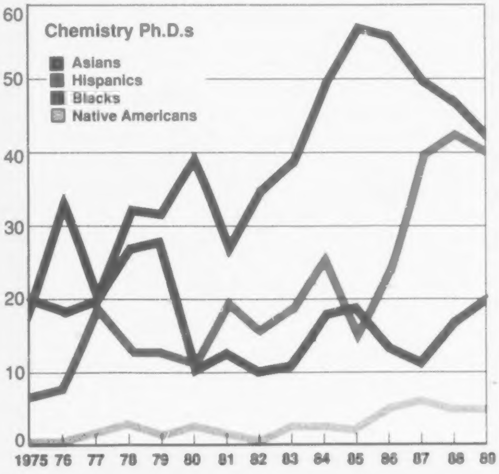
Minority Ph.D.s in natural sciences and engineering are increasing slowly . . .

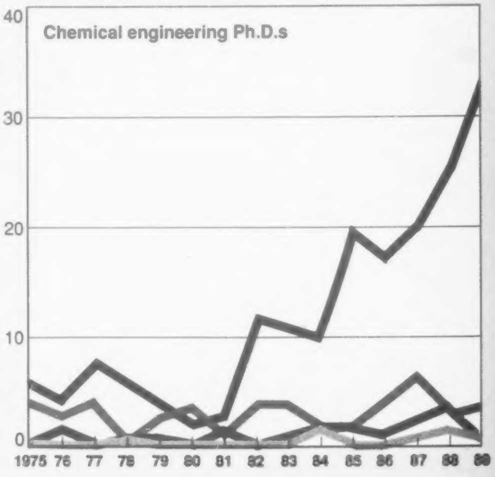
	1989	1988	1987	1986	1985	1984	1983	1982	1981
NATURAL SCIENCES & ENGINEERING									
Whites	7846	7817	7361	7329	7383	7476	7433	7525	7274
Asians	416	362	362	323	304	311	275	257	249
Hispanics	174	187	152	137	117	118	96	107	90
Blacks	108	96	93	86	98	102	94	87	99
Native Americans	34	27	30	31	22	21	14	18	13

. . . but absolute numbers of Ph.D.s remain very low in chemically related fields

	1989	1988	1987	1986	1985	1984	1983	1982	1981
CHEMISTS									
Whites	1161	1235	1243	1182	1219	1189	1248	1191	1102
Asians	42	47	49	56	57	50	39	35	26
Hispanics	40	43	40	24	14	26	19	15	20
Blacks	20	17	11	13	19	18	11	10	13
Native Americans	5	5	6	5	2	3	3	0	1
CHEMICAL ENGINEERS									
Whites	305	293	243	195	181	143	140	113	118
Asians	33	26	20	17	20	10	11	12	3
Hispanics	4	3	7	4	2	2	4	4	1
Blacks	1	4	3	1	2	2	1	0	2
Native Americans	1	2	1	0	0	2	0	0	0
BIOCHEMISTS									
Whites	437	400	384	412	431	463	510	509	501
Asians	24	15	18	23	21	17	17	17	16
Hispanics	9	12	14	11	5	3	6	5	6
Blacks	4	7	6	5	4	4	5	4	8
Native Americans	1	0	0	2	2	1	0	0	1

Note: Data are for U.S. citizens. Natural sciences include agricultural and biological sciences, earth and atmospheric sciences, physical sciences, mathematics, and computer sciences.

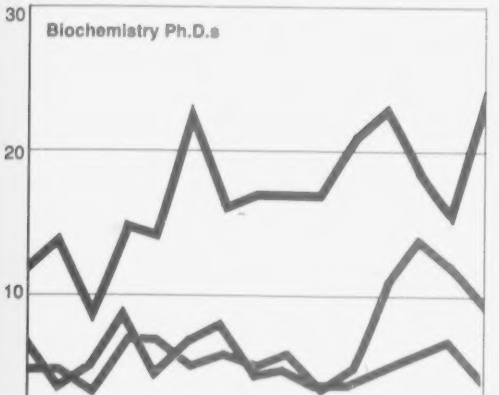




1980	1979	1978	1977	1976	1975
7233	7244	6986	7438	7776	8142
241	234	222	187	197	158
75	90	79	89	64	74
85	106	117	93	93	101
14	10	14	15	3	5

1980	1979	1978	1977	1976	1975
1023	1078	1013	1116	1163	1281
40	32	33	19	34	18
11	13	13	19	8	7
10	28	27	20	18	20
3	1	3	2	0	0
110	123	112	136	137	171
2	4	6	8	4	6
4	3	0	4	3	4
0	1	1	0	2	0
0	0	1	0	0	0
510	448	438	465	453	461
23	14	15	8	14	12
5	7	7	3	5	5
7	4	9	5	3	7
1	1	0	0	0	0

Source: National Science Foundation



groups from fully participating in science careers? Here are the opinions of some people who have been there:

"The number one barrier is lack of academic success, which is generic. It goes beyond science, but you can't do science without being academically successful," says George Castro, president of the Society for Advancement of Chicanos and Native Americans in Science (SACNAS). Castro, a chemist of Mexican descent, is a manager of research at IBM's Almaden Research Laboratories in San Jose, Calif.

"It's a common problem," Castro says, "that the minorities of color face in this country; they have an education system that does not serve them well. There are lots of factors having to do with the curriculum, the teachers, the home environment, and the culture and history of the family toward education and their knowledge of it. Native Americans and Mexican Americans mainly have a background of poverty. Their parents know very little about higher education, don't have much education themselves, and are not prepared to set the intellectual environment at home that causes their children to excel. That's very different from middle-class people in the rest of the world."

Says James W. Mitchell, a black chemist who heads the analytical chemistry research department at AT&T Bell Laboratories in Murray Hill, N.J.: "There are only three things that make kids want to excel. The three things are parents who are aware enough about what is necessary to instill in children the self-esteem, the confidence, and the expectations that they need to have, and to provide them with the discipline that is necessary to take advantage of what the schools can offer them. You need teachers who expect high levels of performance from students and who care about the quality of the product they turn out. And you need the interactions of the parents with the students and the teachers. Then all the other things fall into place.

"My children have gone to a public school, and they perform well because their parents are aware of what they need to do with the teachers and with the kids so that the kids will perform. Unfortunately, for every one set of minority parents who understands and does what's necessary, 10,000 parents either don't understand or can't communicate it in a way that the teachers understand. Therefore, those kids are being lost, and only one gets through."

Norbert S. Hill Jr., an Oneida indian and director of the American Indian Science & Engineering Society (AISES), says: "I don't think public schools do a decent job for white kids; they certainly aren't going to do a decent job for black kids or Indian kids. What's happened in the schooling of people of color has been a process of alienation. There is a lot of violence in the schools, not only physical violence, but psychological and spiritual violence as well, that makes our people unwelcome."

And Marcus Cheney, a Yaki indian and instructor of chemistry at California State University, Northridge, comments, "I don't think all educators are the same, but most of them are. They have no clue about where we are coming from."

Such personal perceptions find support in more for-

Asians are an atypical minority among scientists

Asians are usually thought of as the atypical minority group among scientists and engineers. Unlike blacks, Hispanics, and American Indians, Asians make up a larger fraction of scientists and engineers in the U.S. than they do of the general population. According to data from the National Science Foundation, there were 36,400 Asian doctoral scientists or engineers in the U.S. in 1987, or 9% of the total. By contrast, Asians represent 3% of the work force in professional fields and only about 2% of the overall U.S. work force.

Since 1978, employment of Asian scientists and engineers has been growing 9% per year, or 146% through 1988, which is much faster than the 7% per year growth (or 97% overall) in scientific and engineering employment for whites over the same period. And Asians are more likely than whites or other ethnic minorities to be chemists if they are scientists—13% compared with 8% for all racial groups combined. At the Ph.D. level, 20% of Asian scientists are chemists, compared with 13% of Ph.D. scientists of all races. Asians are also more likely than people of other ethnic groups to have Ph.D. degrees in engineering—35% of Asian Ph.D. scientists and engineers are engineers, compared with only 16% from all races.

But this first-glance picture can be somewhat deceiving. Of the Asian Ph.D. scientists and engineers working in the U.S., one in three is not a U.S. citizen, and of those who are, 85% were not born in the U.S. Thus, 90% of these scientists and engineers are immigrants to the U.S. Some came as children with their parents, but a significant fraction came to the U.S. specifically to study science or engineering in college or graduate school and stayed on.

According to Betty M. Vetter, executive director of the Commission on Professionals in Science & Technology, Asians account for 2% of the U.S.-born science and engineering Ph.D.s in the U.S., a fraction that is the same as their representation within the population. U.S.-born Asians earn Ph.D.s in all fields at a rate that is slightly below their representation in the population, Vetter says, but because they are more likely to earn those degrees in science and engineering than other groups are, they end up equitably represented among Ph.D. scientists and engineers.

"Stereotypes abound about the intelligence and educational achievements of Asian-American children, [but] a closer look suggests that reality is far more complicated than perceptions," says a 1988 report by the Congressional Office of Technology Assessment entitled "Educating Scientists and Engineers." The report concludes that "a lack of research on the interaction of country of origin, social class, and family structure with educational success inhibits understanding of Asian-American participation in the science and engineering work force."

One thing that is clear is that the composition of the Asian community in the U.S. is changing. Most Asian immigrants to the U.S. in the late 1960s and early 1970s came from Hong Kong, South Korea, India, and the Philippines, following a liberalization of immigrant quotas from these countries in 1965. This wave was followed by more than 100,000 Indo-Chinese, primarily Vietnamese, who came to the U.S. following the end of the Vietnam war in 1975. Both of these groups included mostly middle- to upper-income professional people who were fairly well educated, traits that usually indicate that the children of such families will do well in school.

mal studies. For example, the Quality Education for Minorities Project, a joint effort of Massachusetts Institute of Technology and Carnegie Corp. of New York, reported in 1990 that 35 years after the Supreme Court declared segregated schools unconstitutional, most minority children in the U.S. remained in schools that were separate and decidedly unequal. "Quality education is still not available to most minority students, nor is it uniformly available to all nonminority students," the project concluded."

"Our present system of learning ... is clearly inadequate if the nation is to meet the challenges facing us in the 21st century. But for minority students, our educational system is not merely inadequate; it is, all too often, openly hostile and damaging," the report continues.

In a study for Rand Corp. in 1989, Jeannie Oakes, now an associate professor of education at the University of California, Los Angeles, found that the quality of math and science education in secondary schools decreases in direct relation to the number of minority students in the school. Schools with the highest minority enrollments also have the lowest average family income and are much more likely to be located in inner cities. Their resources are fewer, and they offer fewer math and science courses per 1000 students than do schools that have predominantly white students.

For instance, 50% of the schools in her study with 90% or more minority enrollment did not offer calculus as a high school course, compared with 80% that did offer it among schools that were 90% or more white. Teachers in high minority schools were less well paid. They were more likely than in predominantly white schools not to be certified and less likely to have bachelor's or master's degrees in the subjects they taught. Even within a particular school, minority children were more likely than whites to be in classes taught by more poorly trained teachers.

"Oakes' study says that minority students have less of everything that you need in order to do well in science," says AAAS's Malcom, "less well-trained teachers, less facilities, less resources, fewer classes at the upper levels. It's very hard to get through the system if you don't even have available to you the things it takes to be successful."

If education in general is poorer for minority students, it is their lack of preparation in mathematics, in particular, that can cut them off at an early age from science careers. Math is essential training in rigorous thinking for the future scientist, says Bertram O. Fraser-Reid, a black professor of chemistry at Duke University. Fraser-Reid, who grew up in Jamaica, attended a high school there that offered neither chemistry nor physics, yet of the eight people in his graduating class, six now

The late 1970s, however, brought an additional 600,000 Indo-Chinese refugees from Vietnam, Laos, and Cambodia, many of whom were in quite different circumstances from the earlier refugees. They tended to be poorer in their homelands and to come to the U.S. with fewer skills and lacking a command of the English language. Data on the educational attainment of the children of these immigrant families is still incomplete, but some early studies suggest these children find it difficult to learn, some are attracted to drugs and gangs, and many are dropping out of school.

Nevertheless, the stereotype is that Asian students are smart, particularly in math and science. At some schools where Asian enrollment is high—like the University of California, Berkeley, for instance, where close to 45% of chemistry and engineering undergraduates are Asian Americans—students informally calculate what they call the "Asian factor" for various course offerings: If an introductory science or math course has too many Asian students enrolled, non-Asians will drop it on the assumption that the Asian students, being better at science and math, will shift the grading curve and make it more difficult to get a good grade in that particular course.

Agnes S. Sec, a Chinese American doctoral candidate in chemistry at the University of Wisconsin, Madison, has examined the performance of U.S.-born Asian students in the general chemistry courses at Wisconsin. In this study of 6653 students taking introductory chemistry in 1988 through 1990, 4.8% of the students were Asian Americans. Sec found the Asian Americans were just as likely as the class in general to get all As, or As and Bs in these courses. They were somewhat less likely than the class as a whole to get Bs or Cs, and they were about 5% more likely to get Ds, fail, or drop out of these courses. She suggests that the very expectation on the part of teachers and fellow students that Asian students will do well in chemistry actually makes it harder for marginal students who are Asian to succeed.

Another study, this one by mathematics professor Uri Treisman of the University of California, Berkeley, suggests that some of the difference between the performance of Asian students and other minorities—at least in mathematics courses—may be based on study habits, rather than on any differences in ability. In the mid-1970s, Treisman compared the backgrounds, campus lives, study habits, and attitudes of 20 black students and 20 Cantonese-speaking Chinese students taking introductory calculus at Berkeley. At that time, blacks were the least likely of all groups on campus to do well in introductory calculus and Chinese students the most likely to do well. He found that early in the semester the Chinese students organized study groups that met regularly after the students had completed their homework. Group members compared homework results and discussed their perceptions of what the professor expected and of their own adjustment to campus life. The blacks, by contrast, studied alone and maintained a rigid separation between their academic and social lives.

Treisman then set up workshops for black students along the model of what the Chinese students were doing. After a decade of evaluation, he finds that black students who are part of such workshops consistently earn higher grades in their calculus courses (a B- average, compared with C- for nonparticipants), rarely drop first-term calculus, and are more likely to graduate and to major in math.

have advanced degrees in science, mainly, he believes, because of the early grounding they got in mathematics.

"Now, for somebody who is a lousy mathematician, I hate to sing the praises of mathematics!" says Fraser-Reid. "But I think the rigorous thinking that one gets in that study is crucial. Let such-and-such be x, then such-and-such happens. And if that isn't done rigorously, if the answer isn't right, then you didn't treat x properly. That is something that I think has to be inculcated and become second nature at a very early age."

"What are the additional things that prevent our people from going into science?" SACNAS's Castro asks. "One of them is getting tracked out of math courses at the high school level. If you don't shoot for algebra by at least the ninth grade, you are pretty much out of the running to be a scientist. It takes a tremendous makeup afterward. Only with algebra by the ninth grade can students get geometry and trigonometry and precalculus and all the other things that are the language of science."

"We get people coming out of high school with little or no mathematics. I think that is the bottom line," says Henry C. McBay, a black professor of chemistry with a joint appointment at Morehouse College and Clark Atlanta University. "The black students are not coming out of high school with the academic tools, the language skills—and I include mathematics as a language. If they can't do English and mathematics, then they can't do chemistry and physics. You can't start at age 16 or 17 to do chemistry or physics if you haven't had mathematics and English all the way up."

Says Joseph G. Danek, director of NSF's human resources development division: "It's a question of access. You can take any population of school children in any part of the world, and if you put them in an environment where the teachers are poorly trained, there is little equipment, the textbooks are old, and they have to deal with all the other things that are found in the schools where a large percentage of our minority population attends, it's no surprise that by age 13 or 14 these children will be behind. What the problem has been, in my personal view, is that the nation isn't willing to face these problems up front and accept the cost of modifying, restructuring, and changing the quality of education in the urban school."

"But worse than that, we've created an artificial situation in which there are no alternative pathways to successful careers except for children to do well in a very short window that begins at the seventh grade," Danek continues. "By the time they are 17 years old, they are either in or out; if they don't perform within those years, they won't get into a good college or they won't get into college at all, and everything closes down for them. We

Malcom (left): equal access to the enterprise called science. Castro: a great community to belong to

have a mind-set that says, according to the traditional pipeline, you have to progress according to this norm."

Minority students aren't alone in having to deal with these problems of the education system. "Most of the things that happen to black and Hispanic children, to American Indian children, probably aren't unique to them," Malcom says. "It's the accumulation of bad stuff that is unique, something that I think our society is doing to them. If you believe that the process of producing a scientist is one of cumulative advantage, with what these kids have, it ought to be amazing that anybody gets through. What they have is cumulative disadvantage."

In fact, when talking to minority scientists, it's easy to get the impression that in many cases, it was only by extraordinary luck that they became scientists. Every case is different, but Castro's can serve to illustrate how it happens. He credits a temporary move by his family from the inner city to a white suburb for setting in motion the process that led him to a research career in chemistry.

He says: "I was attending a junior high school in East Los Angeles that was a typical ghetto school at that time; that is, it had hardly any white people. It was primarily Mexican, black, some Japanese, some Jewish. I was there with the Mexican and black kids. I didn't notice I wasn't in class with Jewish or Japanese kids. I knew they were in the school, but I didn't understand why we weren't in the same classes; in fact, I didn't even notice it.

"Then for one semester, we moved out to a suburb, and I ended up in a school that was practically all white, in a class where there was one other Mexican student and myself, all the rest were white. This was the eighth grade, and the whole class started to prepare to take algebra in the ninth grade. So I started doing that, and then my parents moved back and I went to my old school again. Since I had gotten geared up to take algebra, I signed up to take it back in my old ghetto school. And then something happened—I was no longer with my old class. I wasn't with the Chicano and black students anymore, I was with the Jewish and Japanese students. My whole schedule changed, so that if I took algebra with them, my social studies was with them, and all of a sudden I found that I was in a new track. I was tracked with the academic kids.

"And once I was there, I could do no wrong. I found out that the Japanese and the Jewish kids were no smarter than I was, they just did more homework. And I never really understood until I was older why there were no Mexican or black kids in my classes. I was just too young to understand.

"The next year, in the 10th grade, I went to high school. There the counselor, whom I had to see before getting into any classes, tried to tell me I had no business in the academic track, that I should go into industrial arts. He said, 'You haven't done all that well in algebra and all these other courses anyway, and I really believe that you should be in industrial arts,' which is where all the Mexicans and blacks were, where you took metal shop and machine shop and wood shop.

"For some reason—it wasn't a strong motivation toward science, I just took a personal dislike to this person—I became ornery and said no. And we left that session with me starting high school on probation; if I didn't have all Cs at the end of the first semester, he would put me in industrial arts. Well, that was all I needed, I hated that guy! I just wanted to see the look on his face when I gave him all As, which was something I had never done in my life.

"You know, I could thank that guy for doing that, but the fact of the matter is, much later in life I talked to my other friends from high school, and they went along with him. They possibly wanted to go into the academic courses, but he talked them out of it. That was the typical kind of thing that happened.

"Of course, when you are going through it, you don't realize the injustice of the system. You don't realize that you have successfully squeezed through a hole in a system that is a wall that prevents other people from going any higher. You can't really see the injustice, you have to be older and look back to do that. Then you say, 'Damn it! It was problematic for me, but all the other Mexican and black kids who were just as smart as I was just got stopped. Their horizons and their opportunities were just nipped in the bud, they never got through it.'

"That system is still in place, and people don't understand that, especially policymakers, people in Washington. Sometimes I hear what they say and how they discuss the problems, and I wonder, have they ever really come to talk to a junior high school teacher who is teaching in a ghetto school? These people haven't changed, these folks still hold the kids down. And they are not evil people; that's just the way it is.

"In fact, the classroom teacher has a lot more problems to deal with now, so they are even more ineffective. They've got drugs and teenage pregnancies and other things to worry about. These are not evil people. It's just that their expectations for minorities are different. It's institutional racism that's built into people. It basically says that what's good is what's like me.

"I went on to UCLA, which was a totally impersonal environment. You don't even get to meet a faculty member until your senior year. You are just one of a thousand people sitting in a classroom. They don't know you, they can't discriminate against you. It is totally impersonal.

"It was an accident that I went to graduate school. My parents had never even finished high school. They were so overwhelmed with the idea of my going on to college that they thought when I finished that it was the most fantastic thing. They had no idea that I was a lousy student, lousy in the sense of not working to my potential. The fact that I was graduating was a big thing to them, but I had a 2.65 grade point average. I never studied on weekends. I was the most unmotivated college student you ever met.

"By the senior year, I had small classes. My class in instrumental analysis had only 20 people. The professor knew me, and he knew most of the people in the course. They were opening up a brand new graduate school at [University of California] Riverside, and they had trouble recruiting students for it. The recruiter was a close friend of my professor's, and the professor said, 'You know, this kid over here, he's not a very good student, but actually, he's a lot smarter than what he accomplishes.'

"So the recruiter came to see me and invited me to go to Riverside. And my faculty adviser at that time said, 'Can you get me some Bs this semester, to show us that you are capable?' And I said, 'Why not? You want Bs? You got 'em.' It seemed a better alternative than the Army, which is what I thought I was going to do when I finished college.

"So I went to graduate school, and that just changed my life. I got totally into science. I left East L.A. and moved on campus. I had money in my pocket for the first time. I didn't hang around with the guys anymore. I stopped doing all the troubled kinds of things you get into in East L.A. I went from an unmotivated student with a 2.65 grade point average to a straight A student, zooming through the cumulative exams, eating up research. It just changed my life entirely.

"The faculty person I was working with moved to Dartmouth College. I had passed all my exams, so the chemistry department arranged for me to finish my research at Dartmouth. I mailed them a thesis, and they

Role of historically black colleges in educating scientists is changing

The role of historically black colleges and universities in the development of black scientists is in flux. Until as recently as the 1960s, not only were black colleges almost the sole places blacks could get degrees in science, they also were one of the few places a Ph.D. scientist who was black could find employment.

In recent decades, however, that picture has been changing. More and more, predominantly white schools are recruiting both black students and faculty into their science programs. "The new code word at universities is diversity," says William M. Jackson, a black professor of chemistry at the predominantly white University of California, Davis. "Universities have finally decided that it's important to get more minorities into science."

The resulting competition for both students and faculty is taking its toll on black colleges. Today roughly 70% of black students going to college are in predominantly white institutions. "Middle-class black kids have the same aspirations as middle-class kids of any ilk," says Henry C. McBay, a professor of chemistry with a joint appointment at two historically black institutions, Morehouse College and Clark Atlanta University. "They want to go—and they do go—to Princeton and Harvard, Yale and Rutgers, and so on. That's a fact of life, and I see nothing wrong with it. But it puts the historically black schools up against the wall when it comes to recruiting the very best quality of undergraduate student."

Black faculty recruitment is also facing stiff competition from nonminority schools. This can be illustrated by a recent attempt by Morehouse to hire a new black faculty member. "We didn't get him because some other place offered him $80,000, and he's just a young fellow, straight out of school," McBay explains. "He's a theoretical chemist, and Morehouse simply couldn't afford him."

Yet despite this competition, colleges and universities with predominantly black enrollments graduate more than half of the blacks who receive bachelor's degrees in the U.S. As Betty M. Vetter, executive director of the Commission on Professionals in Science & Technology, explains, "The assumption has been that the reason black students graduate from black schools at almost twice the rate that they graduate from mixed schools is that black schools have lower standards. But that's not the truth; if it were, so many of these graduates wouldn't be going on to get Ph.D.s. The historically black colleges are a nurturing source. They say to a student, 'Of course you can do it.' They have the black faculty, insofar as anybody has black faculty. They offer the role models."

What they don't offer, with rare exceptions, are well-equipped, state-of-the-art laboratories or the attraction to faculty of world-class research programs. "Black colleges need as many resources, at least, as the white colleges and universities have, and they don't have them," Jackson says. "I've taught at both kinds of schools, and I can tell you absolutely that the black schools don't have them."

Nonetheless, Jackson agrees with Vetter that black colleges often provide a better undergraduate education for black students than do schools whose enrollment is predominantly white. Jackson, who as an undergraduate studied chemistry with McBay at Morehouse, says, "A college education is more than what you get in the classroom. It's also what you learn about yourself as an individual, which helps you to believe that you can pursue goals and targets that are at the highest level. There's no question in your mind when you are at a black college that you can go on and get a Ph.D. because the professors are black, and students before you have done it. You feel that if they have done it, you can, too.

"But at a large white institution like the one where I am now, although we've had blacks get Ph.D.s in chemistry over the past 10 or 15 years, I don't know how many of the black students here know that. These students really don't have a lot of role models in white institutions, and I think that must affect their expectations of whether they can succeed in various scientific fields."

Black students go to black colleges for a variety of reasons, says Jesse M. Nicholson, chemistry department chairman at predominantly black Howard University in Washington, D.C. Their parents, if they went to college, probably went to these schools, and so encourage their children to do so as well. Similarly, the successful black professionals that young blacks see went to black colleges. "There's a feeling of being closer to one's heritage here," he adds.

In addition, black schools seem safer to many students. They are seen as places where students won't have to deal too often with racism and thus can focus their attention on studies or on social interactions with other blacks. And they are places where "teachers are aware of the problems that black students may face and are willing to go the extra mile to help students," Nicholson says. Good teachers do that at majority institutions, too, Nicholson says, "but we have the reputation for doing that."

Says McBay: "There are people who say there is no further need for historically black colleges. But there is one fact I can present for the need to keep these schools that can't be refuted. There is no refutation of the fact that maybe 5% of the entering class at Morehouse College could be accepted into Harvard, but by the end of four years, 40 to 50% of the graduating classes from Morehouse go to the Harvards and the Princetons and earn advanced degrees in competition with people of all kinds. If you didn't have a Morehouse College, if you didn't have a Clark Atlanta University, those human resources would, very probably, be lost."

"The fishnets that are thrown out by the Harvards and the Princetons and the Yales don't encompass little towns in the rural South," McBay continues. "We get some rather remarkable young people who come from far back in the boondocks and who are poorly exposed at the beginning, but who are very gifted and, given the opportunity, outstrip kids who come from Detroit and Los Angeles. Black colleges may be relegated to the role of gleaners in education. But even if that happens, there is justification for black colleges, because there's a large pool of human resources that would not be developed if we were not there."

In fact, majority institutions are working harder to retain and graduate their black undergraduates. Such schools "are finally waking up to the fact that there are good models for retention of minority students," Vetter says. "There are some basic things that almost always are required. If you want to increase your minority students, don't go out and recruit five blacks, five Hispanics, and one American Indian. If you are going to recruit 11 students, make them all black or all Hispanic or all American Indian so that they have a group to work with. Don't try to bring minority students into a situation where there's nobody around who is like them."

Another effective strategy for retaining minority students that many engineering programs use is to bring the students to campus the summer before the fresh-

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mailed me a Ph.D. After that I did a couple of postdocs—one at the University of Pennsylvania and the other one at California Institute of Technology—and then I joined IBM.

"Beginning with graduate school, I got straight As and loved research. And I loved finding out that here was a field where people don't care about the color of your skin. You can become famous without people ever meeting you, just from their reading about the work you've done. I'm Mexican, and these guys don't know it, and this one is Chinese, and this one's German, and this one's Greek, and it doesn't mean anything to them. It's just amazing. A great, great community of people to belong to."

Clearly Castro's is a success story, and the research career that he has is an exciting and satisfying one for him. By and large, successful scientists, whatever their race, feel that way about their work. In a survey of its members conducted last year, ACS found between 80 and 90% of respondents felt that their work was challenging and their working conditions good. This satisfaction level held true for blacks, Hispanics, and whites. There was slight variation between ethnic groups in responding to the general statement, "I'm satisfied with my job." Here 82% of white, 74% of black, and 87% of Hispanic ACS members expressed agreement.

But not all minority scientists share Castro's view of the color blindness of the scientific community. Especially among blacks, many believe opportunities for advancement, particularly in industry, are not so good for them as they are for whites. In the ACS survey, 72% of whites and Hispanics—but only 50% of blacks—thought their employers paid them fairly. In the same vein, 69% of white respondents and 67% of Hispanics thought their chances for professional advancement were good, but only 40% of blacks thought so. And chances for managerial advancement were seen as good by 62% of whites, 61% of Hispanics, but only 29% of blacks in the ACS survey.

Unlike Hispanics and American Indians, blacks have made essentially no progress in the past two decades in increasing their fragile toehold in the scientific professions. At least part of the reason may be because young blacks have heard of the dissatisfaction of practicing black scientists and perceive that their own opportunities will be better outside science.

"Historically, industry has not employed black scientists and engineers," says James Evans, National Organization for the Professional Advancement of Black Chemists & Chemical Engineers (NOBCChE) president. "When students are deciding what they want to become, they look where the opportunities are. You don't man year for a concentrated catch-up program if, as many minority students do, they come from a high school that did not offer them as many upper level courses as their white counterparts are likely to have had. "You can't hold them back once the rest of the students get on campus, or you'll have insulted them," Vetter says. "It isn't that they are not bright—you wouldn't have selected them if they were not bright and able and interested—but many of them simply don't have the background. They come out of high schools that didn't offer calculus, so, of course, they didn't take calculus, or maybe they didn't get physics or chemistry or something else that they need. Most schools, whether minority or not, now understand this."

Weighing the relative advantages of mostly white and mostly black schools is an individual matter, and young blacks will probably continue to choose to go both places. Bertram O. Fraser-Reid, a black professor of chemistry at predominantly white Duke University, argues, for instance, that especially for future chemists, excellent laboratories may be the most important single factor in deciding what school is best. "People are turned on to chemistry, by and large, because of the excitement of the laboratory experience," he says. "Science is a culture, and part of that culture rubs off on you when you are in the lab all the time. Unless a school has the personnel and the resources to run an excellent laboratory, it is a real problem for it to mount an exciting undergraduate program in chemistry. And many minority students are going to minority schools where this situation does not exist. It gets very difficult for them to be turned on to chemistry, even though their teachers are very dedicated, are very good mentors, and are excellent teachers.

"I've had so many young men and women talk to me with concerns about going to majority schools. They are worried that they will lose their black culture and about whether they will experience corrosive racism. My advice is that, yes, you will experience racism. I did when I went to school in Canada. On the other hand, many of the young men and women I met there are my best friends today. So, although you will experience it, I think you just have to rise above it. In my view, that situation will never, ever disappear. It is nonsense to say that I cannot go to that school until every vestige of racism is gone. It will never happen.

"Regarding loss of culture, I assure them that although I left the West Indies 30-odd years ago, all I have to do is step off the plane in Jamaica, and I know where I came from. I don't believe that four years in a foreign institution can make you lose your culture.

"I also advise them that science is also a culture, and it is a universal culture that you are going to share with people of all races. There is only one science, whether you are black, Indian, Chinese, or white. And if that is the case, you ought to be where that culture can be best absorbed. The way to absorb that is with other people who are trying to absorb it at the same time. Not necessarily with people who are focusing on other things. That's the way I see it."

"People have criticized me by saying that most of the black scientists who are practicing today are the product of the historically black schools," Fraser-Reid continues. "And I do accept that; that's the way it had to be, given the racial climate of the time. But I am talking about the cost of mounting a scientific education in the 1990s when instruments cost so much and setting up an undergraduate lab costs so many hundreds of thousands of dollars."

prepare yourself for a field or discipline where you can't get a job. I'm in a position to look at salaries, and there is a real tendency for minority chemists—blacks, in particular—to be lower ranked than their white peers, even when you adjust for length of service, level of degree, and so on."

Philip Merchant Jr., a black program officer with Exxon Education Foundation in Irving, Tex., and immediate past president of NOBCChE, points out that, like whites, many black children decided to study science during the post-Sputnik era of the late 1950s. These people entered the work force in the late 1960s and early 1970s "and quickly realized that their opportunities were not equal. That caused the children of those blacks to not want to study science. So now we have a situation, perpetuated from generation to generation, where fewer black children believe there are opportunities in science for them."

If anything, the climate for black chemists in industry is more hostile now than it was a generation ago, suggests Morehouse and Clark Atlanta's McBay. McBay, who has been teaching chemistry at historically black colleges for more than 40 years, says that in the late 1960s and early 1970s, the people in positions of power in companies were what he calls "wholesome" whites. "The society, the climate, was such that they would have been ashamed to come out and declare themselves as being prejudiced people. But now, with political leadership such as [former President] Reagan has displayed, we have a climate in which people are no longer reluctant. They are up front about their prejudices. And this changes the climate in the workplace."

Not surprisingly, such claims do not go unchallenged by chemical industry employers, and neither McBay nor anyone else is suggesting that all employers are the same. Says Wil D. Carpenter, vice president of Monsanto Agricultural Co.: "You cannot imagine the pressure that's put on me, personally, running a 600-person scientific organization, to get blacks into management positions. If I thought there was anything like an 'old boys' network that was keeping blacks out of management positions, believe me heads would roll. At Monsanto, that is just not the case."

The perception of limited opportunity to move into management positions is something that many companies are working very hard to change, says Carl A. Bauer, director of personnel resources at Dow Chemical USA. "I think even the best companies will tell you that a lot of their minority employees—blacks especially—say they don't see career opportunities. That's why some people quit," Bauer says.

"We've looked at how the minorities who are in the top level of Dow are doing," Bauer adds. "They're doing fine, but there aren't enough of them. What about the next tier? They are doing fine, but there aren't enough of them, either. When we look at the entry to middle-management tier, we find there are quite a few minority people here. Now we're asking, are they getting a fair share of promotion and top performance ratings—and if not, why not? This examination has resulted in the development of an employee development process that, like most good programs, works not only for minorities but for all our employees. Upward mobility is the name of the game—it's our number one goal."

Robert K. Armstrong, manager of professional staffing at Du Pont says, "Unquestionably, what has happened in the past is that blacks have had great difficulty making it in industry. I think the atmosphere for upward mobility in companies has made fantastic strides in the past two to four years. But having said that, you have to realize that upward mobility in a company is not a short-term proposition. You'd be hard-pressed to name one vice president at Du Pont who has less than 15 years' service. Even if the atmosphere is right, you can't promote people from very low to very high. So it will take time, and the perception will be that the change is not going very fast."

"I believe that at the upper levels of almost any organization, they want more blacks to study science," NOBCChE's Merchant says. "They know it is important to them. But I'm not truly convinced that this idea has trickled down to the bottom of any organization. I don't just mean industry, but the government and our educational system, too. Until that is the concept at all levels—that there is a need for equal opportunity for everyone, whether you are black, Hispanic, or whatever, you are not going to have a significant increase of blacks in science."

If the overall picture of efforts up to now to increase minority participation in science is a gloomy one, it is certainly not a picture without bright spots. The Quality Education for Minorities Project found, for example, that although all the answers are not uniformly in place, "we do know how to create a school that helps even the most alienated child feel part of a family of learners . . . [and] how to instill a dream of a career in science in a young girl from rural Puerto Rico." The project found literally hundreds of programs already in place that are working. Two decades of experience have shown "that we know what the problems are and what to do about them," its report concludes.

Several federal agencies—including the departments of Education, Energy, Agriculture, and Defense and NSF—have programs that aim at increasing minority participation in science and engineering. But the pioneer effort among federal agencies—and the one that is most frequently held up as a model of what federal involvement can do—is that of NIH.

NIH began to address the shortage of minority biomedical scientists in 1972 with a program called the Minority Biomedical Research Support program (MBRS). This program focuses on the institutions that traditionally graduate the largest numbers of minority students. The program's initial 38 schools were primarily historically black colleges and universities, but over the years it has expanded to include schools—particularly in the Southwest—that have predominantly Hispanic enrollments, as well as a growing number of large, inner-city universities that attract large numbers of both black and Hispanic students.

"The intent was to build a capacity to do research and research training at these institutions," explains program director Ciriaco Q. Gonzales. "There was not much capacity there, but these institutions were the ones that were responsible for most minority Ph.D.s in biomedical sciences as well as the medical degrees. As far as training minorities was concerned, they were the best."

"Yet they needed facilities," Gonzales continues. "They needed research for faculty. Most of these institutions had teaching as their major function, so we needed to give these faculty time off from teaching to get into research. They needed equipment and renovation of laboratories. And the students needed not only the sort of environment that we set up with the faculty in these institutions, they also needed financial aid. Instead of pushing a broom or whatever they had to do to go to school, they needed financial support, along with the environment and the mentorship to pursue careers in science."

This multifaceted program began with $2 million to spend at 38 institutions. It now operates at about 100 schools with an annual budget of about $42 million. Schools can be at any level—from two-year colleges to Ph.D.-granting institutions—as long as their enrollment is predominantly from underrepresented minorities or they serve a significant minority population in an important way. Montana State University, for example, has an MBRS program, even though minority students make up less than 10% of the school's total enrollment because most of its minority students are American Indians and the school has made a major commitment to provide education for students from each of the state's seven American Indian tribes.

"The ultimate success of our program would be to flood the market with minority Ph.D.s and M.D.s," Gonzales says. That hasn't happened yet, he acknowledges, but "we have been putting people into the pipeline. About 500 students from our program get bachelor's degrees every year. Around 80% of these go on to some form of postgraduate study. About 50% of those go into the health professions—medicine, pharmacy, dental school, or veterinary school—and the other 50% end up in Ph.D. programs in graduate school."

What happens ultimately to program participants is not so well known. "Unless you have a screening program for tracking students that is very elaborate, you can't keep track of them all," Gonzales says. He knows that more than 400 former participants have earned Ph.D. degrees and over 800 now have medical degrees. Over 16,000 students have completed the program, but many of them haven't had time since getting their undergraduate degrees to have completed a doctoral program.

NIH has a second program to increase minority participation in biomedical fields. Intended to complement the MBRS program, the Minority Access to Research

Careers (MARC) program focuses on helping talented minority science majors make the transition from college to graduate or medical school. Each year MARC supports about 500 juniors and seniors at minority institutions. Of the 2700 students that the program has supported since it began in 1976, 80% have gone on to professional or graduate school—compared with the national average of less than 20% of minority science majors who do so. And three quarters of those who start a graduate program complete it. Of that number about 60% earn Ph.D.s, the rest get medical degrees.

"We identify the very brightest students," explains Elward Bynum, director of the MARC program. "We assume that a student with an honors average, given faculty support and monetary support, will translate into an individual who will work harder to improve even that average." Like the MBRS program, MARC also works on curriculum development at the schools where its students are and provides student training equipment, such as water baths and microscopes.

One of the key features of the MARC program is its requirement that all participants leave their home institution and spend at least a summer at a major research institution in some other part of the country. "They go out and gain a lot of confidence," Bynum says. "They see first-rate research laboratories and participate in first-rate research. They work side by side with other undergraduate students, as well as graduate students and postdocs. They get a good feel for what they can accomplish, once they set their minds to it. It works extremely well."

MARC began with a $4 million annual budget, which "may have been commensurate with what we were able to support and still maintain the quality of participants that we wanted," Bynum says. "We just didn't have a large number of minority students interested in biomedical research careers in the beginning." But in recent years the number of high-quality candidates for the program has doubled, in large part, Bynum believes, because present and former participants have become excited about the opportunities they see in biomedical research and are recruiting their fellow students into research careers. For 1992, the program has requested a budget of $15.6 million.

MARC is currently expanding in two directions: Beginning this year it will provide student stipends and other support to freshmen and sophomores, as well as juniors and seniors, at its participating institutions. And the program will also now provide minority students with support for graduate school even if they attend predominantly white institutions.

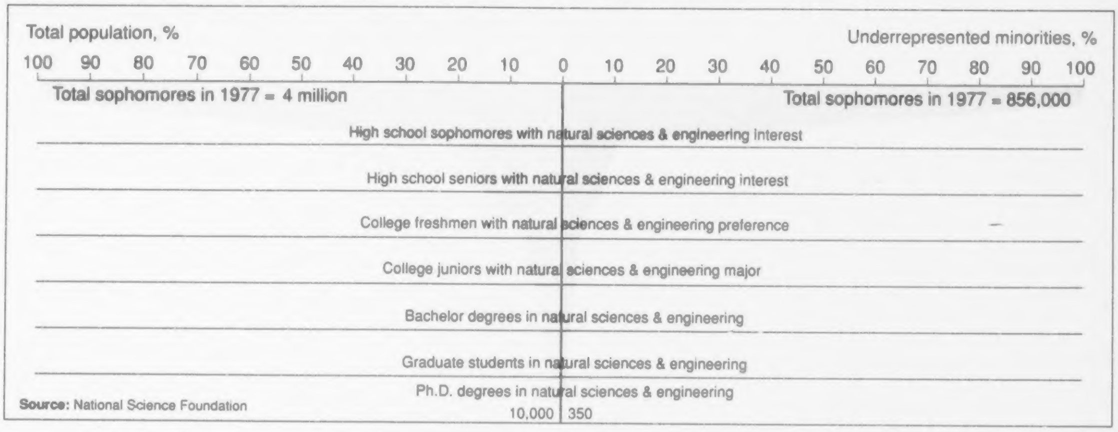
Several nonfederal programs have also been playing an important role in increasing participation of underrepresented minorities in science. For example, the Southeastern Consortium for Minorities in Engineering (SECME), a consortium of 28 engineering schools in eight southeastern states that operates out of Georgia Institute of Technology, runs science and math enrichment programs at 240 of the region's high schools. The program establishes partnerships between local schools, the engineering colleges, and industry, explains founding executive director Carolyn Chestnutt Thorsen. With the approval of the local superintendent or school board, a team of teachers within each school plans the program, as well as reviews and evaluates its success. Industry provides funding and minority engineers who serve as role models for students. The engineering schools put on a two-week training program for the high school teachers each summer, giving them hands-on exposure to what engineers do. "Local planning is critical," Thorsen says, "What works in one school won't work in another."

Although aimed specifically at increasing minority participation in engineering, SECME and programs like it also increase minority access to science careers. The program now reaches 18,000 high school students, 93% of whom are black. Each year for the past 10, 85% of the program's graduates have entered college—compared with the national average of 29% of black high school graduates entering college. And 45% of those in college major in math, science, or engineering. "We've been shocked, quite frankly, by our success," Thorsen says. "The improvements have been beyond our expectations."

C&EN staff photos

Merchant (far left): belief that opportunities are few. Danek: a question of access. Evans: hard work but great rewards

The science pipeline: Minority students leave at higher rate



Source: National Science Foundation

At the University of Puerto Rico, Project CAUSA (Comprehensive Activities to Upgrade Science & Academics) provides science and mathematics enrichment programs for 300 talented Puerto Rican high school students each year. The program provides special math and science curricula, materials, and laboratories to these students in Saturday programs throughout the year and in summer camps. Participants can also participate in research at local universities, be tutored in English, and receive guidance in preparing for college. Like SECME, the program also works with the parents of student participants and offers training for high school science teachers. Since its founding in 1985, every one of Project CAUSA's graduates has gone on to college, with 85% of them majoring in science or engineering.

Both SACNAS and NOBCChE concentrate their efforts on providing young minority students with opportunities to meet and talk with practicing scientists of their own ethnic group. At its annual conferences, for example, SACNAS organizes an evening of informal conversations between practicing research chemists, chemistry graduate students, and college chemistry majors. Similar discussions occur simultaneously among people in other scientific disciplines. In groups of 10 or 12, the undergraduates are encouraged to ask whatever they want to know about going to graduate school and preparing for a career in research.

Almost identical conversations are a highlight of NOBCChE's annual meetings. Here, too, the national meeting concentrates on students, bringing them in from all around the country and giving them a chance to talk to one another as well as to practicing minority scientists. NOBCChE is organized into local chapters in which black chemists work throughout the year with minority students in local high schools.

AAAS's Linkages Project aims to get community groups of all kinds involved in improving science education and opportunities for minorities and other underrepresented groups. Part of that program—the Black Churches Project—provides training and educational materials for church groups interested in providing hands-on science and mathematics projects for black children. More than 500 churches have gotten involved, and last month AAAS held the first of five regional workshops aimed at attracting 180 more churches to the program. Local projects help explain to parents the importance of early math and science education, set up workshops for teachers to learn how to run hands-on science projects, organize field trips to science museums and zoos, plant gardens, and run science-related projects for Boy Scout and Girl Scout troops.

ACS, too, has a long-standing commitment to programs that increase minority participation in science. Project SEED, ACS's career development and social action program, has been operating since 1968. This program focuses on providing exposure to scientific careers to high school students from economically disadvantaged backgrounds. Though the program is not specifically aimed at minority students, more than 60% of the student participants have been from underrepresented minorities, says Sylvia A. Ware, director of ACS's education division, which supervises this program.

In the SEED program, talented high school students spend 10 weeks during the summer conducting research in local academic, industrial, or government laboratories. During this period, the students develop a close relationship with the researchers they work with, and these researchers provide career guidance and serve as role models for the students. In 1989, the program involved 190 students at 78 sites.

In conjunction with NSF, ACS also offers a program called the Young Scholars Partnership, in which 21 high school students—19 of them from underrepresented minorities—supplement their Project SEED experience with a school-year program of counseling, instruction in the ethics and philosophy of science, and special field trips. A highlight of this program is a trip to the SACNAS annual meeting, where the students present posters on their research projects.

ACS has also produced a videotape, called "Working It Out," aimed at pointing out, particularly for black high school students, that there are career opportunities in chemistry for them. The tape features discussions with black high school students, college students, and newly graduated chemists in the workplace.

With all these programs in place, why haven't minorities been making faster gains among scientists and engineers? Several factors may be important. NIH's Bynum points out, for example, that at the same time NIH was setting up its programs to encourage more minority participation in biomedical sciences, federal undergraduate student support programs were changed from grants to loans, which probably decreased the overall number of minority students going to college.

Another troublesome question is just how effective many of the existing programs are. Data simply don't exist to measure the success of many programs. Marsha Lake Matyas, director of the Women in Science Project of AAAS, tried in 1989 to assess the effectiveness of programs at more than 500 colleges and universities that were aimed at increasing participation of women, minorities, and the handicapped in science. Her chief finding was that many programs don't collect the data necessary to evaluate their effectiveness. Only about half the programs she examined know how many of their participants received undergraduate degrees, and many fewer keep track of participants through graduate school and into their eventual careers.

"I have no way of proving this," says Monsanto's Carpenter, "but I believe that if you took the total resources that are available in the St. Louis area to address this issue and used them in a more productive way, you could probably double or triple their effectiveness. There is no central repository where somebody has listed an inventory of the people, organizations, and funds that are available in this area. I've got to believe that there's duplication and there are gaps. We're doing things that should be 30th on a list of priorities and ignoring things that should be first, second, or third. On a national basis, if we could find some better way to coordinate and inventory the resources we've got without creating some monstrous bureaucratic machine, we could do a lot more."

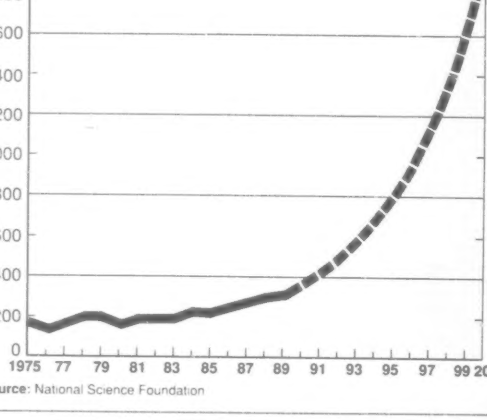
The essence of what Carpenter is calling for may be a role that NSF is trying to take on. Over the past four years, that agency has begun a major new program to increase substantially minority participation in natural sciences and engineering.

In 1986 NSF began looking at minorities, women, and other groups that were underrepresented in science in a more quantitative way. When it compared the total population and minorities, it found that in the minority population, only about 10% of high school sophomores said they wanted to become scientists or engineers, compared with 18% of all high school sophomores who said they wanted to do so. Another major difference occurs between the freshman and junior years of college. In the total population, 63% of freshmen who say they want to study science or engineering will be majors in those fields two years later. For minorities, however, only 35% of the freshmen who want to study science or engineering will actually be doing so by the time they are juniors.

Out of this analysis grew what NSF's Danek calls "a well-reasoned set of programs to attack this issue in a systematic way at every step along the pipeline." The program calls for intervention at three levels—precollege, undergraduate, and postgraduate. The keystone of the precollege programs are 12 comprehensive regional centers for minorities. Established in 1987, these regional centers now have a combined budget of about $15 million per year. "They engage in a whole range of programs," Danek explains, "to improve teacher quality, to bring kids in for day camps, for summer programs, for Saturday academies, to develop leadership by working with parents and counselors. We want to turn around the situation so that what happens in the classroom for minority students builds their sense of confidence, accomplishment, and reward. When people succeed at something when they are young, they like it. That's what we are trying to build."

The middle piece of NSF's comprehensive program—the undergraduate component—is also the newest. Called the Alliances for Minority Participation, the program is in its first year. "We've asked the universities, industry, the states, and the cities to come together and come up with a coalition in a region that is going to significantly increase minority undergraduate participation in the next 10 years," Danek says. "We offer five-year grants at $1 million per year, plus a lot of cost-sharing and foundation and other support." The goal of this part of the program is to increase the number of bachelor's-level degrees in natural sciences and engineering going to members of underrepresented minorities from the current 14,000 per year to 50,000 by the end of the decade and to increase the number of Ph.D. degrees awarded to underrepresented minorities in these fields from the present 350 per year to 2000.

NSF aims to produce 2000 minority Ph.D. scientists per year by end of decade



Source: National Science Foundation

To meet these goals, the alliances are going to have to dramatically plug some important leaks in the pipeline that produces science and engineering professionals. "We want to see a dropout rate for students in these alliances that is almost nonexistent between the freshman and junior year," Danek says. "In three to five years, we are looking to see changes. If we are going to go from 14,000 baccalaureate degrees per year to 50,000 in 10 years, we've got to see a 15% increase every year."

The alliances will actually focus on two points in the pipeline where minority students are lost—the high attrition period between the freshman and junior years in college and the transition between finishing high school and entering college. As NSF's Williams points out, there is a pool of minority high school graduates "who complete high school having taken all the right math and science courses and whose scores on college placement tests indicate they would be successful in undergraduate science or engineering majors. But about 35% of these youngsters don't go to college. So part one of the program is to engage that 35%."

The program is ambitious, Williams says, because it aims to engage "not a fraction of the 35%, but the majority of them and attract them into colleges and universities." It's also realistic, he suggests, because its success "doesn't depend on learning how to get an increased number of minority students through the precollege sector. The students have already done that themselves; they are simply not going on to college, or if they are going on, they are not staying with their intent to major in science or engineering."

The third component of NSF's program is a set of programs designed to improve minority faculty research and training opportunities. The effort pulls together two programs addressing these issues that NSF began in the early 1980s—the Research Improvement in Minority Institutions Program and the Minority Research Initiation awards and planning grants—and adds to them a newer program (begun in 1987) to develop large-scale minority research centers of excellence.

In this large-scale program, "we're working with six minority institutions now and we are going to go to eight," Danek says. "We're trying to develop the research training capacity at eight of the most productive research-oriented minority institutions. We know that there are a number of minority students who would go to a high-quality program at one of these institutions who won't go to programs at Stanford or Harvard or some other first-class majority research institution."

Altogether, the three components are requesting $45 million in the 1992 federal budget, up from about $7.5 million that their predecessor efforts received in 1986. "These are not NSF's only efforts with regard to minorities," Danek points out. "These are our targeted and focused efforts. NSF has an education and human resources budget request for 1992 of $390 million for a set of activities that the foundation believes will help solve some of the educational problems in the country.

"At the same time, we know we are not living in an ideal world. We need specific intervention programs for minorities at certain points along the pipeline. You can look at the $390 million education effort and think of the $45 million as an intervention that is going to perturb the system. The effect of the two systems interacting will generate a much more effective system over the long haul. Eventually, the objective of these programs is to no longer be needed as minorities, women, and persons with disabilities, who are now underrepresented in science, become part of the mainstream in science."

Although $45 million is a substantial amount of money, NIH is already spending $56 million on its minority intervention programs and Williams estimates that funds from all sources currently directed at this effort total on the order of $200 million per year. How realistic is it, then, to expect another $45 million to produce a nearly fourfold increase in minority scientists and engineers at the bachelor's level in just eight years?

"Frankly, given the magnitude of the effort, even if its success rate is only 30% of what we envision, it still would be an extraordinarily positive undertaking," Williams says. Meeting 30% of NSF's goal would roughly double the number of minority scientists and engineers graduating each year. "I think anything less than a doubling of minorities would not be a success," Williams says, "but if we could, in fact, double the current level of production, that would be an extraordinary contribution."

NSF may meet its goals by the year 2000, suggests AAAS's Malcom. "If people have to go around and basically rediscover how to do everything, they will not make it," she says. "But if NSF will provide not just money, but help in building on the experience and talent that we already have, we can meet these goals. If they don't do it at all, there's no way it will happen. But if they do it right, we have a chance."

"I'm very encouraged with NSF's new initiatives," says Jesse M. Nicholson, chairman of the chemistry department at Howard University. "The idea of starting very, very early to try to convince young people that there are tremendous numbers of opportunities in science is something that is very much needed." As to whether NSF will actually meet its goal of graduating 2000 Ph.D. scientists and engineers per year by 2000, Nicholson says, "You set your goals high. I think if output doubles in that time, it would be a welcomed improvement. But no, I don't think NSF's goals are going to be realized unless a great deal more money is put into this effort. You'd have to make it extremely financially rewarding, sort of buy people into the area, to meet those goals."

Thirty years ago, in the post-Sputnik era, a federal program called the National Education Defense Act basically did that, Nicholson says. "Students got $2000 to $2400, and at that time, that was good money," he explains. "There was a need to get scientists, and that level of financial support was enough to sort of drag students into the field. And then, of course, once they got into the field, they saw that the work was really fun, and they liked what they saw. Now there needs to be something like that again."

Says AISES's Hill: "The gains that I am seeing are promising, but we can't put a Band-Aid on a long-term problem. The investment is generational, and I don't

C&EN staff photos

Nicholson (clockwise, top left): new NSF initiatives encouraging. Bynum: biomedical programs gaining because former participants are excited and are recruiting. Gonzales: ultimate success would be flooding the market with minority Ph.D.s and M.D.s

think we can fix up 200 years of educational deficits in one or two funding cycles. . . . Getting an engineer is a process and not an event, and the year 2000 is not a magic point when we are going to have this process completed. If it thinks that way, NSF will be disappointed. I'm not hopeless, I'm just saying we've got a long way to go. We haven't even approached the halfway point yet."

"We're going to change things," says NOBCChE's Evans. "We're going to make it happen for a number of reasons. One of them is that there's talent among minority young people that's waiting to be used. But the real reason is that science is fun. We scientists work hours that we would probably do for free if we had another job and someone said, 'Here's a laboratory, you can go over there and play whenever you want.' We do science because it's fun and stimulating, and that's not cultural; it's probably true for anyone you talk to. There's clearly a lot of hard work necessary to become a scientist, but the rewards are great. I can't tell you when it's going to happen, but for all these reasons, we're going to make it happen."

But there is some real time pressure on present efforts to try to improve minority participation in the sciences and engineering. Long-time observers point out that present efforts will need to start showing results soon—and substantially better results than earlier programs have—if they expect to continue to be widely supported. These efforts, after all, are fueled in large part by the pressing concern that shortly there may not be enough scientists and engineers to supply the nation's need for workers in science and technology fields.

And there are other ways to meet the need for scientists and engineers. For instance, the immigration laws could be changed to make it easier for foreign graduate students to remain in the U.S. once they complete their studies. Foreign students continue to flock to the U.S. to study science and already make up an important component of the country's scientifically trained work force. Immigration policy could also be changed to encourage foreign-trained scientists to immigrate to the U.S.

There are two ways of responding to the expected shortage of scientists, NIH's Gonzales points out, "We can either train our own people here, or we can go get foreigners. Which way we are going to go is up for grabs right now."

For several reasons, training our own seems, for now, the preferable option. As Roosevelt Calbert, head of the minority programs section at NSF explains, "a good analogy is the oil crisis. We have become dependent on somebody else to send us our oil. If we do the same thing in human resources, we will be in trouble. If we lose our capability to train our own personnel, our own work force, if we have to depend on someone else to send us those trained people, we'll be in the same kind of trouble that we were in the oil crisis."

There may be even more important reasons than national security for choosing to improve minority participation in science. "We have a larger issue here," Malcom says, "about whether we really think that talent is distributed within all the groups in our society and whether we think we can hold a democratic society together where only certain people do certain things, and we don't look to other groups to provide those skills. I don't think that's the way a democracy works; that's not what America is about. So the questions really are about equal opportunity, equal access, developing human talent, and allowing potential to be expressed, as well as meeting national needs for people to be involved in the enterprise that's called science." □

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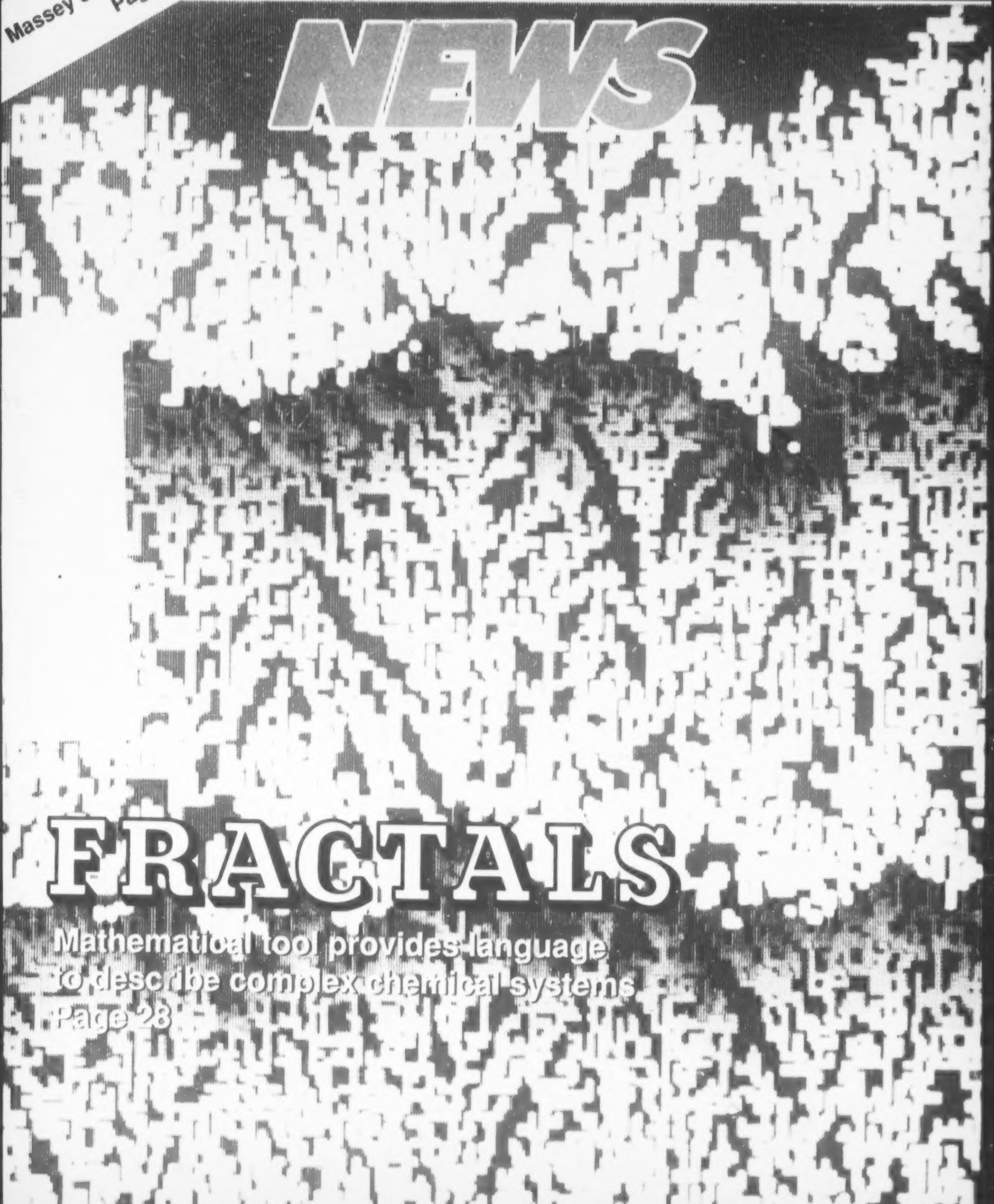

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Cover: Courtesy of Fereydoon Family

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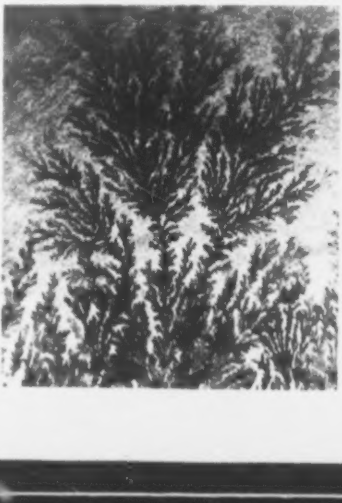

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Fractal geometry, a mathematical language that describes irregular shapes in terms of noninteger dimensions, finds growing use in chemistry. **Page 28**

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Subscription Rates 1991. Printed editions: nonmembers U.S. 1 yr. $95, 2 yr. $171; outside U.S. 1 yr. $131, 2 yr. $243. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3–10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $12. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Hiring older chemists

The ACS Comment by John S. Connolly, "Economic Status of Chemical Professionals" (C&EN, Feb. 18, page 37) is a breath of fresh realism compared with recent handwringing over the demographics of chemical employment typified by your article on the "Campaign for Chemistry" (C&EN, Dec. 17, 1990, page 37), which sets "critical needs" for use of solicited funds to include "the need to maintain an adequate supply of scientists and engineers."

Connolly accurately points to the older unemployed as a source of scientists and engineers, and notes that they actually are available in excess of the 1% statistic since some who are laid off near retirement age do not seek employment. And even 1% averages to five months' unemployment over a lifetime career.

As an older, multidegreed unemployed engineer, I can report from the field that Connolly only understates. There are so many experienced chemical professionals chasing so few jobs that personnel departments have found it convenient to adopt de facto rules of thumb that may keep some of us from ever regaining meaningful employment. Engineers and scientists in charge should become aware of, and try to reduce, these roadblocks.

One troublesome rule of thumb is that anybody unemployed is obviously no good. I overheard this directly from a company recruiter. These days, activity in many product divisions and much academic R&D—as well as industrial—is being reduced (C&EN, Jan. 14, page 20). Even those forewarned can end up unemployed, for once rehired, seniority disappears, and that engineer or scientist can well be the first to go if the new employer cuts back.

A second rule of thumb says, "Only those with current experience doing exactly what we want done will be considered." This probably cuts a pile of résumés by 75%, mostly at the expense of more experienced people whose last employment category is by definition not in current demand. Rapid screening using this rule can be done by clerical help, who cannot appreciate that an older candidate can be more adaptable, by virtue of his or her disparate experience, than one with the "two to five years of experience" so popular in the ads. Incidentally, how can one have five years of experience without having two? C&EN should not accept such ads except for positions in which age descrimination is defensible.

The continuing presence of early retirement programs is prima facie evidence that there is no shortage of scientific or engineering personnel. A third rule of thumb also refuses to consider those early retired for further employment. While not suffering the full financial burden of unemployment, the early retired are a vast labor source, often anxious to continue their work. They also suffer from rule two.

A fourth rule of thumb dictates consideration of only those candidates who will not be moving. The chronically under- or unemployed scientist or engineer may be trapped in his or her geographical area because prospective employeers wish to avoid paying moving (or interviewing) expenses, and the candidate cannot logically move without a new job to go to.

A fifth rule of thumb from recruiters says, "We won't hire a candidate into a lesser position than he last had." This is what is meant by being overqualified. Evidently most organizations dislike unused competence! It is surprisingly difficult to get an entry-level position at entry-level salary when overqualified. Often the only alternative is to leave the profession.

Curiously, I know of one clever company that hires only older scientists and

Correction

• March 25, page 26: Citations were inadvertently omitted from several of the figures in the Special Report on Ion Trap Mass Spectroscopy. They should have been cited as follows: The figure on page 27 is from Wuerker, R. F., Shelton, H., Langmuir, R. V., *J. Appl. Phys.*, **30**, 342 (1959) (figures 5 and 11). The upper figures on page 33 are from Hayward, M. J., Riederer, D. E., Kotiaho, T., Cooks, R. G., Austin, G. D., Syu, M-J., Tsao, G. T., *Process Control Qual.*, 1, 105 (1991) (figures 5a and 5c). The lower figure on page 33 (top half) is from Kaiser, R. E. Jr., Cooks, R. G., Syka, J. E. P., Stafford, G. C. Jr., *Rapid Commun. Mass Spectrom.*, 4, 31 (1990) (figure 3a). The bottom figure in the box on resonant ejection on page 35 is from Kaiser, R. E. Jr., Louris, J. N., Amy, J. W., Cooks, R. G., *Rapid Commun. Mass Spectrom.*, 3, 226 (1989).

U.K. chemical capital spending takes dip

Capital spending by the U.K. chemical industry fell 8% in real terms in 1990 from 1989, and the predictions are that it will fall another 4% in 1991. That was the main message from the annual investment intentions survey of the U.K. Chemical Industries Association (CIA) in London earlier this month, a survey that accounts for roughly 80% of total U.K. chemical spending.

Moreover, the downward trend is predicted to continue into 1992 and 1993. A longer and deeper recession, with delays in further interest-rate reductions, would result in even greater cutbacks to the industry's spending program, the association's economists added.

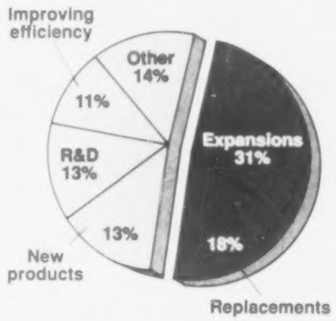
That the U.K. is in a recession, and has been since the latter half of 1990, is no surprise. However, said Keith Wey, CIA's senior economist, "the speed and severity of the recession was greater than had been expected, and had forced many companies to reappraise their spending. In fact, the level of spending now expected for 1991 and 1992 combined is almost a third lower in real terms than forecast in last year's survey."

Total fixed capital spending for 1991–93 is estimated at about $10.5 billion in current prices—roughly $3.25 billion less than predicted last year. And 1991 figures probably will be overly optimistic, the association conceded somewhat gloomily.

In analyzing 1990 actual performance from that which had been forecast a year ago, CIA said that of the companies responding to its detailed questionnaire, 27 spent less than forecast, five spent more than intended, and one was right on target. Deepening pessimism and uncertainty brought more decisive action than in previous years. In 1989, some 74% of the underspending was attributed to postponements and rephasing; in 1990, only 54% was. However, whereas in 1989 only 13% related to cancellations, last year cancellations accounted for 38% of the underspending, according to CIA.

Spending plans for petrochemicals and plastics have many execu-

Expansions, replacements lead investment plans



1991–93 chemical industry investment = $10.5 billion[a]

[a] $1.00 = £0.53 on Dec. 31, 1990.
Source: U.K. Chemical Industries Association

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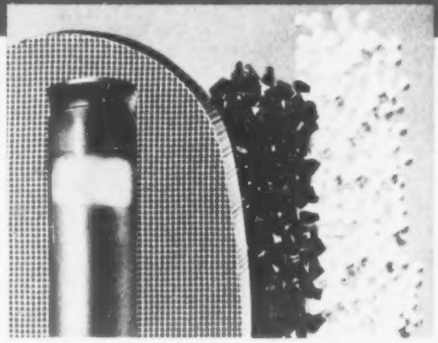

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tives in the industry concerned about possible overcapacity. "In our recent history, the U.K. chemical industry has had a patch with excellent profitability, good margins, high plant utilization, and outstanding return on capital," points out Bryan Sanderson, chief executive officer of BP Chemicals.

The good times have led to a spate of new project announcements, he says. Some of these may never come to pass, but others certainly will. "Even with an optimistic view, an expansion program of ethylene means that utilization will fall to about 90%. With a no-growth scenario, utilization will fall to the mid-70s. Our forecast is somewhat pessimistic; we think it will be closer to no growth—which leaves room for concern."

According to Sanderson, "One would hope that investment intentions would be reducing, particularly in respect of capacity expansions, leaving only those projects based on genuine competitive advantage."

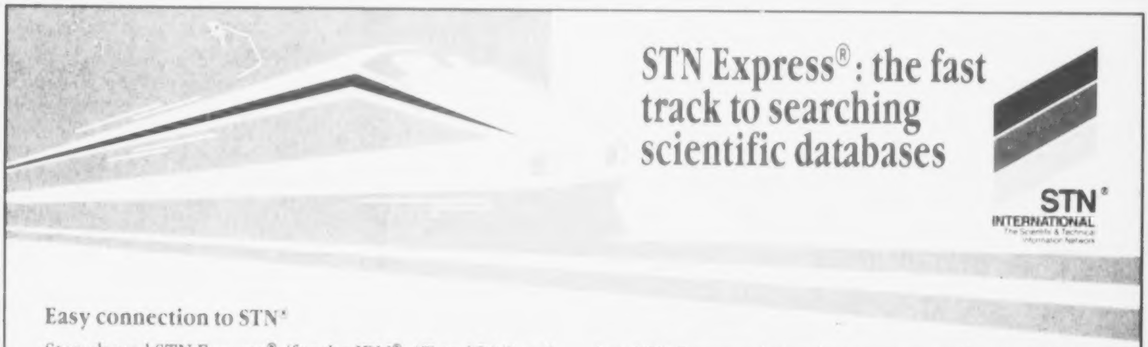
The only areas showing probability of consistent spending growth are environment, health and safety, and energy savings. These areas accounted for 11% of the industry's capital expenditures in 1989, but this is expected to more than double to an average of 28% of all capital spending from 1991 to 1993. Of that, 11% will be for energy saving, another 9% for environmental protection, and 8% for health and safety measures.

According to Clive Thompson, vice president, Arco Chemical Europe, answers to the specific environmental questions in the spending-intentions survey showed that two thirds of the companies said they are increasing expenditures as a result of internal decisions, in contrast to 33% who are doing so as a result of regulatory pressures.

Most of the expenditures—47% in the years 1990-92—would be going to water protection, Thompson says, with an increase in spending of 127% from 1989. Waste cleanup and disposal will take another 29%, representing an increase in spending of 146% from 1989. The total chemical industry waste disposal cost of nearly $400 million in 1990 represented an increase of 33% over 1989, and similar increases are seen for coming years.

All told, it was a gloomy outlook for the next three years. However, CIA economists point out that in the last recession, the drop in U.K. chemical spending from its peak in 1978-80 to 1981-83 was 36%. By that measure, the fall of 14% in real terms from 1988-90 to 1991-93 is somewhat less painful. According to CIA, although competitiveness has deteriorated over the past year, the U.K. is in a better position than at the start of the 1980s, and levels of surplus capacity throughout Europe are not so high as in 1980. Moreover, environmental spending now regarded as essential is much higher than 10 years ago.

Patricia Layman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Walter Massey Takes Over Helm of National Science Foundation

New director brings a softer approach and a clear idea of changes necessary to guide the nation's preeminent science agency into the 1990s

Wil Lepkowski, C&EN Washington

When physicist Walter E. Massey was picked last fall to succeed Erich Bloch as director of the National Science Foundation, science watchers in Washington had one big question on their minds. Would Massey—or wouldn't he—follow in the footsteps of his predecessor, Erich Bloch?

Most hoped he wouldn't. The voltaic Bloch, they felt, tramped with hobnailed boots through the manicured gardens of academic science. His aim was to shift the culture of basic science in the U.S. by tying NSF-supported research more closely to industrial, engineering, and economic themes. In form at least, Bloch fulfilled his agenda. He transformed the image of NSF as an agency insulated from the U.S.'s economic challenges to one in which most of the major technological research frontiers would be engaged.

Although Bloch did the right thing politically, he succeeded in alienating much of the basic science community. Academics accused him of wrecking the spirit of the basic research enterprise by taking money basic researchers thought they deserved and applying it to expanded engineering and education programs. Bloch told them the country had real problems, that they should be thankful for the substantial sums NSF already was giving them, and that they should stop acting like spoiled, entitled brats. Academic cheers rose and mugs were lifted when the Bush Administration decided last year not to give Bloch another six years at the NSF helm.

If engineer Bloch stalked the science scene in heavy boots, Massey steps onto the stage in designer shoes, an engaging manner, and a lot of empathy for academic values. Colleagues say no person could be more equipped for the tasks before him—mollifying the basic research establishment while reconciling it further to economic purposes. Bloch was blunt. Massey is tactful and subtle, and that should win him friends in Washington.

Massey is 52 years old and the second black—after his friend John B. Slaughter, now president of Occidental University in Los Angeles—to run NSF. He has traversed many worlds in his time, from physics to music to civil rights marches down South, and has seen success in them all. His origins are in the deep, segregated South of Hattiesburg, Miss., where his promise was spotted so early that by the 11th grade he was sent off to college. The school was Morehouse, a historically black college in Atlanta with its legendary president, Benjamin Mays, who Massey recalls as a "towering figure in black higher education."

Morehouse was a place, Massey recalls, "where one learned discipline, self-motivation, self-responsibility, and postponement of gratification. It was very valuable, especially for many of us who were from small towns. We certainly didn't have any social graces, but we got a healthy knowledge of what would be required to be successful. We also had role models right there who demonstrated that this was not just theoretical material. They showed us that it had worked."

C&EN staff photo

Massey: change only in emphasis

Massey is concerned about the high attrition rate of minority students with technical skills. The thought of dropping out of science never occurred to him, mainly because, as he puts it, "I went to college early." He adds, "It's amazing. I used to read this book about the great migration when blacks left the South. But it's funny, I don't think attrition meant anything in Hattiesburg, Miss. You just went to school, period—unless your parents were dead or you were sent to reform school. There was no question of that."

Massey took his time coming to Washington when his nomination was announced last fall. He was comfortably positioned as vice president for research at the University of Chicago but at the time of selection was preparing to go to Europe under an NSF contract to study European Community science policies. In the meantime, deputy NSF director Frederick M. Bernthal, a chemist and protege of former Sen. Howard Baker, ran the agency while Massey toured that continent's research centers.

He has plenty of experience in the field of government, education, and competitiveness, beginning with his most recent job at Chicago. There he had responsibilities for the university's research program as well as for the Department of Energy's Argonne National Laboratory, which the university is under contract to manage.

Prior to that, Massey headed Argonne and spread his time around by serving during different periods on the National Science Board and the President's Council of Advisers on Science & Technology. At Argonne he formed a program designed to bring companies together with universities and Argonne in efforts to develop new research-based technologies. Massey established a program of dialogue between scientists and journalists in Chicago to improve understanding between the two different worlds of inquiry. A musician (tuba and saxophone to name two), Massey serves on various arts and cultural committees around Chicago. In addition, he also is a member of several corporate boards.

With a background that spans the kinds of cultures the agency now routinely interacts with, Massey seems ready to shape NSF for the unpredictable 1990s. He's concerned about the U.S.'s domestic and international problems but, along with most observers of science policy, says he isn't much concerned about this nation's losing its international lead in fundamental research. "We still have the world's best system of research and training," he says. "But other countries are investing in basic research at a faster rate than we are. And they will get more competitive in the long run."

Still, Massey believes the pressure put on NSF to connect research more closely with competitiveness will only increase. "The policies grew under Erich Bloch's NSF and I support them," he says. "I don't think we should be decreasing our emphasis on fundamental research, but we're going to need more programs that make that link. I don't see where emphasizing one deemphasizes the other."

Massey says he has no plans to make any big structural changes at NSF. "It will continue to reflect the nation's needs. I do think there will be some changes in emphasis though. We've put into place a number of programs under Erich and Congress has encouraged us to put a number of others in, like in education. Many of these programs are fundamentally different in character from the traditional base of NSF."

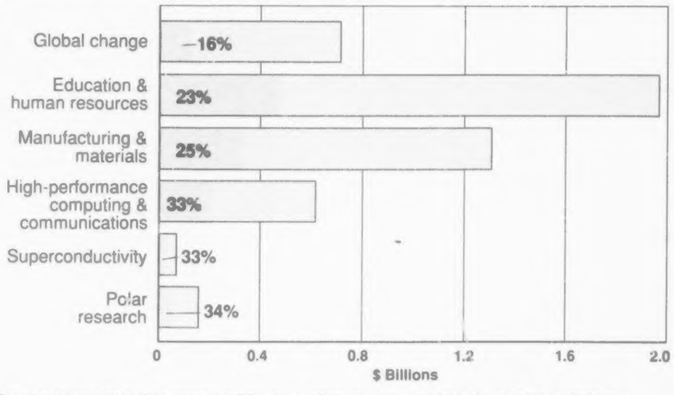
Accordingly, he has set up task forces to reevaluate NSF's international programs, its entire program evaluation, policy evaluation, and data analysis activities, and its role in technological competitiveness. Of some concern are serious delays being encountered in preparing the next Science & Engineering Indicators report, which is also being revamped. Also under study is whether the agency's scattered programs in the environmental, Earth, and geophysical sciences ought to be recombined in ways that better reflect their interconnections. And under review is the popular Presidential Young Investigator awards, which critics say need to reflect peer-based selection rather than well-crafted letters of recommendation from elite mentors.

Massey says NSF's role traditionally has been to judge by peer review processes the competency of the individual researcher, the quality of his or her research. "It had not been our role to follow up and see whether that research had any applications," he says. But he adds that because NSF is now investing hundreds of millions of dollars in education and human resources and big university engineering centers, Congress and the public have a stake in knowing how successful they are. "These are programs that ought to be measured," he points out. "We ought to be able to see that we are making some visible contribution over some agreed upon period.

"So we will be doing more to determine how we measure the return on these investments, whether we can find ways to see if in fact we are accomplishing what these programs are designed to do. So in many of these programs we will be putting in evaluation mechanisms, more than we have in the past; looking into long-term strategies and how they are paying off; and trying to set measurable goals to which we can be held accountable."

One example of needed evaluation Massey points to is in the so-called Statewide Systemic Initiatives program in which NSF funds renewal of whole education programs in entire states. Evaluation mechanisms are part of the grant proposal for this program. Another program Massey is especially high on is Alliance for Minority Participation. One of its goals is to decrease attrition among those who already have shown an interest in science, math,

NSF funds healthy percentage in critical R&D areas



Note: Based on fiscal 1992 budget proposal; NSF's share of $76 billion federal R&D budget is 3.6% or $2.7 billion.
Source: National Science Foundation

and engineering. "Attrition of people with natural talent in science is one of our biggest losses," Massey laments. "If we could turn that around it would be the most effective thing we could do. This program won't just consist of giving grants to institutions to do that, but will have milestones to measure how we've done."

Also slated for more attention is NSF's role in bolstering "feeder" colleges—the small liberal arts institutions that supply the bulk of successful Ph.D. students. Massey is one of the stellar examples of one who came out of such a system and went on to a distinguished graduate and research career. "There are still students who for many reasons," he says, "are not accepted at the majority institutions but who are very talented, have a great deal of potential and ability, but need more time and maybe a nurturing environment but one with tough standards. That's what these schools have traditionally done."

Massey says NSF is establishing programs, for example, that make use of mentors in the development of scientific talent in colleges—activities that would "bring undergraduates into the lab to give them a sense of how science is done and establish personal relations between students and faculty members."

Massey acknowledges NSF will be playing a role in President Bush's "new world order," but admits that he doesn't quite yet have a sense of Bush's concept. The agency already has offices in Paris and Japan where research in Europe and the Far East are monitored. Would Eastern Europe be next? Possibly. "It's one of the areas we are looking at internally now. The international area is one that's motivated by lots of things—first by the changes in Europe, new opportunities and challenges everywhere, and by the fact that more and more major projects require more international cooperation. And there's always been the question in my mind of whether we are doing enough to provide opportunity for our scientists and engineers to have international experiences and contacts."

One of the most politically sensitive issues Massey will have to face on Capitol Hill is the government's role in the funding of new laboratories on campuses. NSF, under a laboratory facilities act Congress forced on it three years ago, has funded in modest ways some facilities in various levels of colleges and universities ($20 million for fiscal 1991). For fiscal 1992, however, the Office of Management & Budget eliminated the program, which was never very popular at NSF anyway. Although White House science adviser D. Allan Bromley, who had wanted $200 million in the budget for facilities, opposed the action, NSF had to go along. Massey is concerned, too, but speaks diplomatically about it. What the universities got instead was $50 million in new instrumentation support.

He admits the facilities problem is serious but believes universities have tended to look too much toward the government to solve it. "Facilities [improvement] is going to require a national approach," he says. "It's too big for NSF alone to do it. But a national approach means that a lot of things have to be looked at in universities."

Massey says facilities are only a small part of the issues that need looking at in universities anyway. "There's not only the sufficiency of direct funding for facilities but also indirect costs, depreciation rates, and ways to encourage that the depreciation portion of indirect costs actually goes into rehabilitiation and upkeep of buildings. One problem I am familiar with from my Chicago experience is the impact of the 1986 tax bill, which put a cap on the amount of tax-exempt borrowing the institutions could make. So it's not direct funding but all the things that affect the university's ability to invest in capital facilities. That is being looked at and Bromley's office is trying to organize it in a more comprehensive way."

Massey also has thoughts on the issue of misuse of indirect cost funds that have put universities in a bad light lately. "If one looks at research dollars going into universities, they've obviously gone up. On the other hand, faculty feel that they are under more pressure than they have been. So what's the disconnect? I think we're asking the wrong question when you limit yourself to saying how much federal research dollars are going to institutions. One has to ask what is the amount of total federal support—from student loans to facilities—going to these institutions. Looking at the total, I would suspect that the amount is not at all increasing.

"If you look at the whole range of issues I think you're going to find that the ability of universities to support research by themselves has been limited. What the individual faculty member sees is that they no longer can hire technicians because the university can't pay for such costs. Laboratories no longer have a glass-blowing shop, they don't have a machine shop or an electronics shop. All of it has to be charged to their grants now, and what they see as direct discretionary funds for research are being constrained. I can't prove that yet, because I don't have the data. But I think that's what we should be looking at, and we're going to do that here."

So when Massey says he is not planning many changes at NSF, a qualifier should state, "for now." He is concerned that the reputation of science has slipped in the public eye and that the image needs a lot of repair. He is pondering ways of involving scientists more in the political process. He plans a heavy schedule of outside ambassadorial activities on behalf of federal science and NSF. A new directorate on the behavioral sciences probably will be established, opening new vistas for NSF in applying those fields to attacking the country's social problems, largely neglected during the Reagan years.

Thus, Massey's plate seems full for the next six years. But will he stay the full term or will he follow his career pattern of moving on when a better job beckons? "Accepting this job was a major decision," he says. "My wife and I and my family discussed it. I never really thought I'd come to work in the federal government. It's just not something I wanted to do. This came about through a set of circumstances I didn't seek, so I'm just going to see how it goes. I'm assuming that if I do a good job here, the future will take care of itself." □

Scientific news from the Atlanta ACS meeting

APRIL 29, 1991

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Precipitated Calcium Carbonate

New uses in papermaking spark demand growth Page 9

CHEMICAL & ENGINEERING
NEWS
APRIL 29, 1991

Volume 69, Number 17
CENEAR 69 (17) 1–48
ISSN 0009-2347

News of the Week

- **Report detailing 22 technologies considered critical to the U.S.'s future is issued by panel formed by White House Office of Science & Technology Policy under Congressional mandate.** Page 4
- **In aftermath of castigation of Stanford for billing the federal government for inappropriate indirect research costs, universities scramble to review their accounts, and Office of Management & Budget issues tighter rules.** Page 5
- **Iraq files letters describing its chemical, missile, and nuclear programs; U.S. says report is incomplete.** Page 5
- **President Bush stresses his support for math and science education to educators attending summit on mathematics last week at the National Academy of Sciences.** Page 6
- **Chemical operations will be hit hard in Olin reorganization that includes selling several chemical operations and eliminating 250 salaried positions, among them chemists.** Page 6

Cover: Pfizer's precipitated calcium carbonate plant at International Paper's mill in Ticonderoga, N.Y.

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Government

Dioxin health risk is getting another review by EPA as the result of new studies and reports indicating the need for an updating; new greenhouse gas report by NAS recommending action now to slow the accumulation of such gases in the atmosphere is substantial shift from academy's earlier position. **Page 13**

Science/Technology

From the Atlanta meeting: Mathematical lumping techniques could simplify and improve atmospheric modeling; advances made in olefinic metathesis polymerization; membrane separation and catalytic chemistry eyed for stack-gas cleanup; direct methane conversion challenges catalytic chemistry; new photogenerated amine catalysts developed at Cornell. **Page 17**

Education

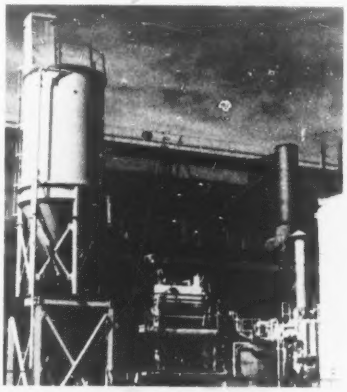
Also from the Atlanta meeting: ACS task force on chemical education critically assesses undergraduate chemistry curricula and calls for radical changes in emphasis and approach. **Page 26**

Books

"**Science and the Soviet Social Order**" documents many dimensions of the interactions of science, technology, and societal development with the U.S.S.R. **Page 30**

ACS News

Photos from society's national meeting give a view of the wide variety of activities and events in Atlanta. **Page 32**



Business

Precipitated calcium carbonate is finding growing market as cost-saving mineral filler in longer lasting acid-free paper, accelerating transition from traditional acid paper. Page 9

Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

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Subscription Rates 1991. Printed editions: nonmembers U.S. 1 yr. $95, 2 yr. $171; outside U.S. 1 yr. $131, 2 yr. $243. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $12. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210.

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LETTERS

Approving new drugs

Ann M. Thayer wrote a cover story on biopharmaceuticals (C&EN, Feb. 25, page 27) in which the Food & Drug Administration's process for approving new drugs was described. She stated, "Upon completion of clinical trials, a product license application, as it is called by FDA's Center for Biologics Evaluation & Review, which handles biotechnology drug products, is filed."

We would like to draw to your attention that many biotechnology drug products are reviewed and regulated by the Center for Drug Evaluation & Research. These biotechnology drugs reviewed by the center include, among many others, superoxide dismutase, epidermal growth factor, human growth hormone, and human insulin as appeared in the list on page 32 of Thayer's article. For these products, a new drug application is filed with the Center for Drug Evaluation & Research for marketing approval. In fact, the new drug applications for human insulin and human growth hormone (the first two approved biotechnology products) were approved in 1982 and 1985, respectively.

Yuan-yuan Chiu
Chairman, Biotech Committee
Center for Drug Evaluation & Research
Food & Drug Administration, Rockville, Md.

Political environmentalism

Kudos to Charles M. Krutchen for his letter on polystyrene foam (C&EN, Feb. 11, page 38). Almost simultaneously, *Science* published Martin B. Hocking's excellent analysis, "Paper versus Polystyrene: a Complex Choice," in the Feb. 1 issue. Shortly after, A. Alan Moghissi (C&EN, Feb. 18, page 3) developed the terms "scientific environmentalist" as opposed to "political environmentalist," with reference to other environmental problems.

Taken together, these three articles stress the seriousness of letting political environmentalism continue to take its toll of sound chemical products such as polystyrene foam. Krutchen says that the "attack on polystyrene foam is really an attack on the chemical [and, I would add, the plastics] industry. . . . How many more chemical products will go down before the chemical industry finds effective means for defending itself?"

I would suggest that one counterattack would include the form of analysis presented by Hocking before and during the development of consumer products. Such analyses should then be advocated before and during the commercialization of such products. Then the scientific environmentalist may prevail over the political counterpart.

George W. Ingle
Hampden, Mass.

Are environmentalists our deadly nemesis, launching an all-out attack on the chemical industry, as stated so colorfully by Charles M. Krutchen? I believe that Krutchen's assertions are totally unfounded, particularly with respect to the specific case he highlighted: McDonald's decision to no longer use polystyrene "clamshell" containers. Along with other polystyrene advocates, Krutchen has grossly misinterpreted the results of the Franklin Associates report that he quoted to bolster his argument.

First, and most critically, the Franklin report specifically examines only two types of fast food clamshell containers: polystyrene (about 5 g per container) and paperboard (about 15 g per container) as used by several fast-food outlets. The goal is to determine the life cycle environmental impact, cradle to grave (so to speak): energy requirements, air and water discharges, industrial and consumer solid waste. The Franklin report finds polystyrene to be significantly superior to paperboard; McDonald's is not switching to paperboard, however. It is switching instead to a paper-based wrap (about 5 g per container) that is environmentally superior to polystyrene on all counts! Using figures calculated from the Franklin report, paper wrap uses 55% less energy in manufacture, and produces 45% less air and water discharge and 80% less consumer solid waste, relative to polystyrene. Krutchen, either knowingly or unknowingly, published serious disinformation in his letter.

Another misleading characteristic of the Franklin report is that their figures are for total input and output. For air emission, for instance, they lump together all emissions, making no attempt to accurately gauge health effects. Consider that benzene and styrene (both are toxic and carcinogenic) figure prominently in polystyrene air and water emissions, while ozone-depleting chlorofluorocarbons (CFCs) and now pentane hydrocarbons are used in polystyrene blowing. By contrast, unbleached paper wrap and paperboard emit mainly sulfur dioxide, nitrogen dioxide, carbon monoxide, and carbon dioxide. While these figure prominently in acid rain, risk from exposure to TCDD, mostly by human consumption of fish that have levels of TCDD acquired by eating other, lower organisms.

It's possible that even if EPA changes the risk estimate for TCDD, its overall cancer risk might not change if the agency modifies its estimate of average fish consumption, a matter of some controversy itself. So the question of bioavailability of TCDD will be reviewed as well. Reilly has requested that all agency actions related to TCDD, either under way or planned, be checked for any appropriate changes while the special reassessment is in progress.

EPA is not going to do this activity single-handedly. Reilly has committed the agency to a wide open review. "It needs to be carried out with the broader scientific community," he says, "with a view toward assuring that our reassessment is accepted as objective." EPA will probably reach out to other federal regulatory agencies in an effort to build a consensus on this new toxicity model.

The EPA review will take place concurrently with a Congressionally ordered study of the same kind by the National Academy of Sciences. Although EPA has not taken NAS's activity into account, the two studies likely will overlap considerably. EPA is under the gun for some answers regarding TCDD and its timetable is quite tight, with Reilly asking for quarterly reports and a completed reassessment in a year. The NAS review is not under the same pressure and probably will take longer.

Several environmental activists have already expressed doubt about any EPA move that might make TCDD appear less dangerous. TCDD has long been named as one of the most toxic chemicals known to humans on the basis of its carcinogenicity to lab animals, and it would be somewhat of a blow to environmental organizations concerned with the regulation of toxic chemicals if animal tests were found to be not so reliable as these groups have been stating. Although TCDD may be a special case, it could force industry and EPA to reevaluate other chemicals.

David Hanson

NAS greenhouse gas report signals new stance

The prestigious National Academy of Sciences' new report, "Policy Implications of Greenhouse Warming," may mark a turning point in the U.S. response to the complex issue of global climate change. While acknowledging great uncertainties in both the science and economics of global warming, the report recommends taking action now to slow the accumulation of greenhouse gases in the atmosphere (C&EN, April 15, page 5).

That recommendation does not go beyond the conclusions of the United Nations-sponsored Intergovernmental Panel on Climate Change report that was completed last year. Nor does it surpass what several European countries have advocated for some years. But the new academy stance is a substantial shift from its 1983 position on the subject. And it endorses a much more aggressive approach to the problem than that currently espoused by the Bush Administration, which encourages greenhouse gas control measures only if they can be justified on other grounds.

"As is usually true for NAS reports, the report is significant less for any new ground it breaks than it is for whom is saying it," comments Alan Miller, director of the University of Maryland's Center for Global Change. "It is significantly different from the Administration stand. It clearly sends the message that there is a tremendous amount that can be done that would even save money."

In this case, "who is saying it" is the Committee on Science, Engineering & Public Policy (COSEPUP), a joint committee of NAS and its sister organizations, the National Academy of Engineering and the Institute of Medicine. The 126-page report, prepared by a "synthesis panel," presents the principal findings of three other COSEPUP panels that have been studying the issue for about two years at the request of Congress. Daniel J. Evans, former Governor of and Senator from Washington State, chaired the synthesis panel.

They concluded that increases in concentration of carbon dioxide, chlorofluorocarbons (CFCs), methane, and nitrous oxide likely will result in a rise in average global temperature of between 1 and 5 °C by early in the next century. Then, much like a recent report by the Office of Technology Assessment (C&EN, April 1, page 7), they evaluated the options available for reducing emissions of those gases. U.S. emissions could be cut 10 to 40% from 1990 levels at little or no expense, they find.

At a news conference where the report was unveiled, Evans described the measures recommended

Panel lists cheap ways to limit greenhouse gases

Mitigation option	Net cost of implementation	Potential emission reduction [millions of metric tons of CO_2 (or equivalent) per year]
Energy efficiency in buildings	Net benefit	900
Vehicle efficiency	Net benefit	300
Industrial energy management	Net benefit to low cost	500
Transportation system management	Net benefit to low cost	50
Power plant heat-rate improvements	Net benefit to low cost	50
Landfill gas collection	Low cost	200
Halocarbon-CFC usage reduction	Low cost	1400
Agriculture	Low cost	200
Reforestation	Low to moderate cost	200
Electricity supply	Low to moderate cost	1000

Note: Net benefit = cost less than or equal to zero; low cost = cost between $1.00 and $9.00 per ton of CO_2 equivalent; moderate cost = cost between $10 and $99 per ton of CO_2 equivalent in the report as an "insurance policy" in the face of a real problem of as yet unknown magnitude. "Nobody knows for sure" what the consequences of not acting would be, he said. "We believe the time to act is now. A whole lot of people in San Francisco bought insurance the day after the earthquake. This set of insurance policies is a worthwhile one to make."

In addition to ways to reduce greenhouse gas emissions, the report recommends taking steps to prepare for a warmer climate and higher sea level. "Even with the most aggressive mitigation measures," Evans said, "we will not see a world where greenhouse gas concentrations would actually decrease. We're going to have to adapt."

To ease adaptation, the panel recommends a vigorous agricultural research program to ensure ample food. Water supplies should be better managed and water conservation encouraged. Construction projects should incorporate margins of safety in the face of an uncertain future. For example, building bridges higher above sea level now, rather than raising them later to accommodate rising water levels.

Another section of the report discusses so-called geoengineering options for fighting global warming, a set of untested technological fixes. They include adding iron to the ocean to stimulate growth of carbon-dioxide-absorbing phytoplankton and using lasers to break up CFCs in the atmosphere.

Also proposed are several ways of reducing temperature by screening sunlight. Among them are placing 50,000 100-km^2 mirrors in Earth orbit; launching billions of aluminized hydrogen balloons into the stratosphere; and burning sulfur in ships or power plants to form sulfate aerosols that would induce clouds.

The report recommends against taking any such actions now, but suggests they could end up being relatively inexpensive last-resort options if all else fails. More research and development is needed, the report says, to understand both the geoengineering options' potential to offset global warming and their possible side effects.

Pamela Zurer

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Mathematical Lumping Techniques Could Benefit Atmospheric Modeling

MIT engineer describes how "lumping" could simplify computational analyses, help forecasting of global warming and the global CO_2 balance

Joseph Haggin, C&EN Chicago

ATLANTA

A prominent chemical engineer has suggested that some of the techniques of mathematical lumping, long used in the chemical industry, might profitably be applied to the analysis of global warming problems. Taking some of the existing guesswork out of modeling computations could permit the development of policies that are more effective and more equitably applied.

Weather predictions in the short term and climate predictions in the long term are based on the use of atmospheric circulation models, explains James Wei, professor of chemical engineering at Massachusetts Institute of Technology. One commonly used model, he told the Division of Industrial & Engineering Chemistry, divides the atmosphere into 10 levels in the vertical direction, 22 divisions between the poles, and 36 around the equator. These divisions define about 8000 atmospheric cells that circulate over Earth and carry the weather with them.

The cells are not all the same size. The entire surface of the U.S., for example, is covered by only 10 cells, which are too large to permit very localized weather forecasting. Even so, to make a reasonable simulation of the atmosphere using these cells requires about 400 hours of computation time on a Cray-1 supercomputer.

The computational problem will probably get worse because, as Wei describes the problem, the "climate community" is already talking about a higher resolution of atmospheric cells—that is, more smaller cells—by making the present grid 10 times smaller. Computations using such a grid would require a 10-teraflop (10^{12} floating point operations per second) computer. If political policy decisions were ever to be based on data issuing from such a model, then the computational requirements would need to be even further extended to require a petaflop (10^{15}) computer. In the language of the chemical engineer, "simplifying assumptions are necessary" to reduce the problem to a more manageable form. One might be the employment of "lumping" techniques in analyses of atmospheric behavior in the future.

The basic idea behind lumping is the partitioning of variable space into a manageable number of states, invariably with the sacrifice of precision but with the virtue of computational manageability. Mathematicians have used the technique in the analysis of Markov chains and elsewhere. Wei and his associates applied the technique more than 20 years ago to the analysis of catalytic reforming processes in which a great number of molecular species were involved. In the physical world, lumping invariably involves less than ideal choices of "lumps," but the technique is no less valid because of that.

C&EN staff photo

Wei: simplifying assumptions needed

Wei has been investigating the problems of global warming and the global carbon budget. The problems are related but distinct. The first step that must be taken in solving them is to more precisely define them. This requires a better forecasting model than is now available. In the case of the anthropogenic emission of carbon dioxide, Wei notes that the atmosphere contains about 740 billion tons of CO_2 growing at a rate of about 3 billion tons per year, with the ocean absorbing another 3 billion tons. The prospect usually presented is that, if the atmospheric greenhouse gases double in concentration, the average temperature on Earth would increase 1.5 to 3.5 °C. This would probably have serious climatic effects in the next century.

The 5 billion people on Earth contribute to the 5 billion tons or so of CO_2 emitted each year. Additional deforestation and unenlightened land use may add an additional 2 billion tons. If Earth's population doubles, as some predict it will, then carbon emissions may become too great to tolerate.

Wei believes it clearly is nec-

Lumping system has nine economic categories

	Basic parameters of carbon emission			
	Population, millions	GNP ($ billion)	Energy consumption (10^{18} joules)	Carbon emission (billions of tons)
U.S. plus Canada	270	4,860	82	1.4
Upper income Eastern countries	170	2,380	20	0.3
Western Europe	337	4,380	54	0.7
U.S.S.R. plus Eastern Europe	372	2,600	73	1.4
Upper middle income countries	433	1,170	16	0.30
Lower middle income countries	610	730	12	0.20
India	798	240	7	0.15
China	1069	310	20	0.50
Others	957	270	7	0.15
TOTAL	**5016**	**16,940**	**291**	**5.10**

Note: 10^{18} joules, an exajoule, is 0.95 quadrillion Btu.

essary to find a scheme not only for analyzing the atmospheric circulation, but also for lumping the sources and effects of carbon generation and consumption. How one does the lumping is debatable. The United Nations Environmental Program divides 100 of the world's nations into seven classes that are not very useful from the mathematical viewpoint. The U.S. Environmental Protection Agency uses another scheme that tends to lump nations by national wealth. And the World Bank divides 120 reporting nations into three income groups and doesn't include 10 nonreporting nations.

Wei has devised his own lumping system. It has nine economically designated categories: the U.S. and Canada; Eastern countries in the Organization for Economic Cooperation & Development plus other high-income Eastern countries; Western Europe; the U.S.S.R. and Eastern Europe; upper middle income; lower middle income; India; China; and other low income.

The larger emitters of CO_2 are evident, although for different reasons. The U.S., for example, simply consumes more fuel, but China is also a big emitter because of low combustion efficiency. Wei has developed some parametric ratios that are pertinent to his analysis, including $/P, the gross national product per capita; E/P, the energy intensity per capita; and C/E, the carbon intensity of energy use.

At any given time the rate of carbon emission is the product of these ratios and the population: $C(t) = (C/E)(E/P)(\$/P)(P)$. Manipulation of and derivations from this equation are useful only if reliable data can be obtained in each country. This may be difficult to do. In any case, with Wei's model, the principal variables are national wealth, population pressure, energy intensity, and carbon intensity in energy use. Not everyone agrees with this suggestion. If the lumping scheme is good, says Wei, then the four growth rates for the variables would behave uniformly in each region. This may be a difficult requirement to impose, even within a single nation.

The eventual need for enlightened public policies will require the best possible model of the atmosphere and the carbon balance. Every decision will cost money, force changes in life-styles, and produce other effects on the populations of the nations. Among other things, policies that are optimum would be based on hard data. Anything else would be a guess.

It seems clear that each policy decision should target some form of carbon reduction, and there must be incentives to impose it. Above all, Wei says, the costs must not exceed the anticipated benefits. It is equally clear that there may be changes in societal behavior, in technology, or in both. Wei sees four driving forces effecting the anticipated changes, one related to each of the four ratios mentioned above.

Maintaining or lowering the present population is the most controversial of the possibilities. Personal morality plays a key role, and it is not clear who will accept or reject this alternative. Deliberately checking economic growth is equally controversial and would require superhuman statesmanship, which probably doesn't exist. Both of these changes are purely societal, but there are two more that are equally technical. One is changing the energy intensity of a nation through conservation, increased efficiency, and substitute energy sources. The potentials here are very great. Finally, it may be necessary to change the carbon intensity of energy use by decreasing the use of fossil fuels. The obvious things are employment of nuclear energy, hydro-energy, tides, wind, and the like. Biomass may be a useful fuel, if the rate of burning doesn't exceed the rate of reforestation.

Among the proposals that have been made in this respect is the use of energy transfer payments between nations. It may be more cost-effective for Sweden and the Netherlands, for example, to pay for more efficient furnaces in Poland than to incrementally improve their own, which are already rather efficient. Rich nations that emit more carbon oxides than poor ones would have the same emissions quota nonetheless. An effective transfer of payments might result if the rich nations could buy emissions permits from the poorer ones. This raises numerous political problems, however, since the poorer nations might thereby be encouraged to further increase their already bulging populations to acquire still more permits. Still, Wei believes that this is a solvable problem.

In the last analysis, there is a prime need for a reliable model for atmospheric operation and the global carbon budget, among other things. These will remain intractable problems until some lumping scheme is developed that can reasonably function on available computers. Wei's scheme is one of many that will be offered, but it does suggest that the seemingly intractable problem may not be so intractable after all. □

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More scientific news from Atlanta ACS meeting

MAY 6, 1991

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Volume 69, Number 18
CENEAR 69 (18) 1–84
ISSN 0009-2347

CHEMICAL & ENGINEERING NEWS

MAY 6, 1991

News of the Week

- **Federal agency science funding should double in the 1990s, urged NAS president Frank Press at the academy's annual meeting. Page 6**
- **Costs of complying with future environmental regulations could seriously hurt credit ratings of companies, warns report from Moody's Investors Service. Page 7**
- **Chicago company and five executives acquitted of criminal charges of damaging workers' health by exposing them to toxic chemicals. Page 7**
- **NASA rolled out its new upgraded space shuttle, *Endeavour*, giving the agency four operational shuttles for the first time since the loss of *Challenger* in 1986. Page 7**
- **Duty-free treatment will end for imports of ibuprofen from India, giving boost to Ethyl Corp., sole U.S. producer of the analgesic and anti-inflammatory drug. Page 8**
- **A number of chemists are among the 60 new members and 15 foreign associates elected to the National Academy of Sciences. Page 8**

Business

OSHA-sponsored study of safety issues related to contract worker use in the petrochemical industry may lead to significant policy changes; commercialization of growth hormone that boosts milk output in cows is held up by negative public reaction, extended FDA review. **Page 23**

Government

What constitutes discrimination and harassment in the workplace and what workers face if they file charges was topic of major symposium at the Atlanta meeting; recent environment report is used by President Bush as evidence of his Administration's strong progress in this area last year. **Page 27**

Science/Technology

From the Atlanta meeting: Mechanism of action of anticancer drugs that modify DNA is becoming clearer, offering hope for design of more effective, less toxic drugs; more rational approaches to drug discovery from natural products described; analytical chemists make progress in characterizing large molecules; new study validates Dalton's data; globalization of R&D backed by Japanese executives; California researchers propose new strategy for optimizing optical nonlinearity; EPA study finds pesticides, nitrates in U.S. wells; infant/toddler exposure to household pesticide hazards measured; researchers offer new insight to metal-heteroatom bond chemistry; need for building electric power demonstration plants questioned; gas separation research yields new membrane materials, uses; modeling software for polymers, general uses unveiled. **Page 31**

ACS News

ACS Council boosted dues for 1992, adopted one petition, defeated another, among other actions at meeting in Atlanta last month. **Page 60**

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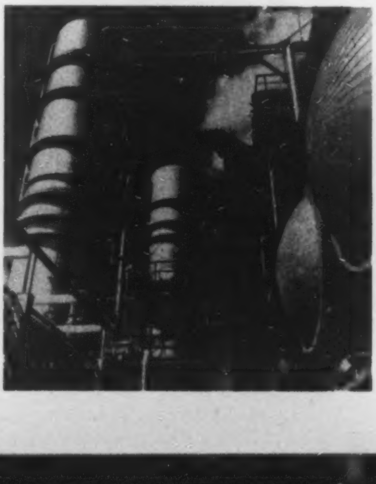

News Focus

Combined sales of the 100 largest U.S. chemical producers posted another record in 1990, up 5% over 1989 to $185 billion; profits, however, fell for most companies. Page 11

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Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

RU-486 controversy

Rudy Baum's article on RU-486 (C&EN, March 11, page 7) was very informative and interesting, but revealed an ethical position that concerns me. The overriding impression coming from the researchers interviewed was that "RU-486 exists, therefore I should be allowed to use it." But should knowledge be pursued just because the means are available? I believe that ethical concerns should be considered.

The introduction basically claims that since abortion is legal, access to this drug should be unaffected by the abortion debate. However, the legality of an issue does not determine its morality, as was seen in Nazi Germany when human experimentation was legally allowed—but few will consider that it was morally right. Regardless of the legality of abortion, or one's personal stand on the issue, the fact is that use of this drug involves ethics, and ethical discussion on RU-486 would be advisable. The quotations from the American Association for the Advancement of Science meeting on RU-486 do not give the impression that the goal was to discuss the ethics of RU-486, but rather to demand its availability.

Roussel-Uclaf's caution in supplying the drug unconditionally is to be commended, even if this is more for image's sake than for purely ethical reasons. On a different point, it is of note that Ariel Mouttet of Roussel-Uclaf states that the U.S. fails her company's criteria on two points, and yet no further mention is made of the lack of a synthetic prostaglandin in the remainder of the article.

If science is to remain truly human we must give ethical considerations in research an adequate hearing. My hope is that ethical concerns will not be dismissed simply because they are ethical and may adversely affect our research goals.

Donal O'Mathuna
Visiting Assistant Professor of Chemistry
Capital University and Mt. Carmel
College of Nursing
Columbus, Ohio

Rudy Baum's article brings to focus many of the issues surrounding this important steroid analog. Baum rightly alludes to the highly charged emotions and politics that befall not only RU-486, but all matters dealing with abortion in the U.S.

With a well-educated and critical audience that is particularly well suited to comprehend the chemical implications of RU-486, Baum had the opportunity to present the facts surrounding RU-486 in an unembellished and straightforward manner. It was disappointing, therefore, to see him trivialize opposition toward introduction of RU-486 into the U.S. by those who oppose its potential use as an abortifacient. In establishing the background for this approach, Baum characterized abortion as widely accepted in American society, while making no distinction in the fundamental difference between a society that accepts abortion in and of itself and one that recognizes the established judicial right of a woman to have such a procedure.

The lack of such a distinction, coupled with an imbalanced and less than flattering portrayal of RU-486 opponents, leads one to conclude that impediments to the introduction of this drug into the U.S. are due chiefly to a small number of simple-minded zealots who do not reflect the interests of society at large. This biasing detracts from an article that otherwise contains useful information, and that provides a valuable service by bringing to scrutiny the potential benefits of RU-486 for a variety of noncontroversial uses.

Terrence R. Burke Jr.
Bethesda, Md.

Accuracy of Superfund samples

It is with a feeling of disbelief that I write this response to the article, "Contract Labs Charged with Fraud in Analyses of Superfund Samples" (C&EN, Feb. 25, page 14). In the past I have managed such an Environmental Protection Agency-sponsored program and thus was filled with dismay to read that the 10-day sample storage has no scientific basis. The other equally disappointing statement in this article contains the phrase, "determine roughly what is in the complex waste samples and about how much."

I am under the impression that sample storage deadlines adopted for Superfund are from the *Federal Register*, which is printed as a result of an act of Congress. The statement of work of the program explicitly states that generated analytical data be quantitative in nature and also be legally defensible. I wonder about the utility of the Superfund program as such, particularly because now we all know that its protocols include sample storage constraints based purely on avoiding the piling of the samples at labs, and on the quality of analytical results that represent only rough determinations.

Top 100 Chemical Producers Post Overall Sales Improvement

1990 was another record year with total sales up 5%; sales fell for 36 firms, however, and chemical operating profits suffered at most companies

William J. Storck,
C&EN Northeast News Bureau

Last year was not the worst 12 months for the U.S. chemical industry, but it was a year that brought many problems for chemical producers already weakened during much of 1989 and the first part of 1990. In the second half of 1990, the industry ran up against sagging demand in many sectors in both U.S. and foreign markets. And it was hard hit by increasing raw material costs.

The result was declining profits and profitability. However, in spite of the problems, the industry managed to increase sales during 1990. And the sales dollar increase was not all attributable to inflation. In spite of everything, there was a small amount of physical volume growth.

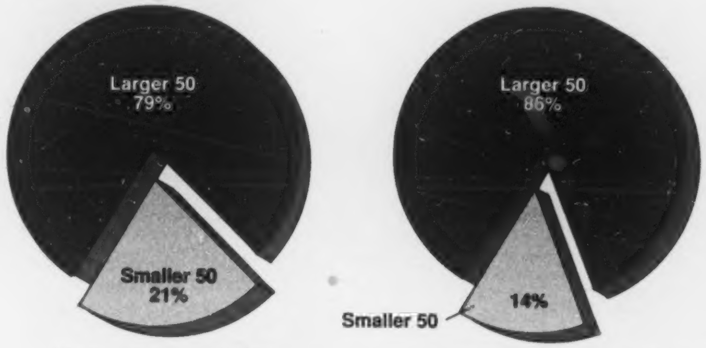
To put the relative importance of the companies comprising C&EN's annual ranking of the Top 100 chemical producers into perspective, their aggregate sales of chemicals accounted for almost 70% of the value of U.S. shipments of chemicals and allied products last year. And their chemical sales made up more than 6% of shipments of all U.S. manufacturing industries in 1990.

The increasing dollar volume is reflected among the companies included in the Top 100. Sales for the chemical companies in the 1990 ranking increased about 5% over 1989 to about $185 billion. There was some attrition among the larger firms in 1990 (for instance, BP America is no longer on the list), but sales for the 100 chemical-producing companies listed were up an average of more than 2% over the companies in the 1989 ranking.

In spite of the increase in total chemical sales for the 100 companies, not all were in the plus column. In fact, 36 of the companies registered declines in chemical sales for 1990 compared with 1989. Of the remaining companies, 60 had higher chemical sales last year than the year before, and the remaining four either recorded no change or comparable 1989 figures were not available.

The contributions of the different categories of companies to total sales remained relatively constant for 1990. The 50 largest companies continued to more than dominate the

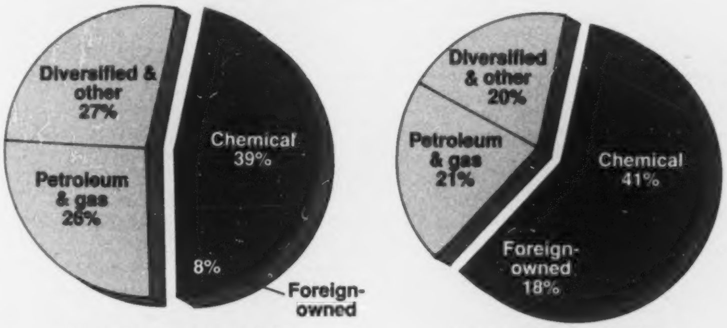
In past five years, larger companies have increased their dominance . . .



1985 sales = $126 billion

1990 sales = $185 billion

. . . and chemical and foreign-owned companies have taken bigger share of sales



1985 sales = $126 billion

1990 sales = $185 billion

Note: Based on chemical sales figures for Top 100 producers in 1985 and 1990.

Sales of the Top 100 chemical companies totaled about $185 billion in 1990

Rank 1990	Rank 1989		Chemical sales 1990 ($ millions)	Change from 1989	Chemical sales as % of total sales	Industry classification	Chemical operating profits[a] ($ millions)	Change from 1989	Chemical operating profits as % of total profits	Operating profit margin[b]	Identifiable chemical assets ($ millions)	Chemical assets as % of total assets	Operating return on chemical assets[c]
1	1	**Du Pont**	$15,571	2.1%	38.9%	Diversified	$1968	−28.9%	40.1%	12.6%	$13,788	36.2%	14.3%
2	2	**Dow Chemical**	14,690	3.6	74.3	Basic chemicals	1925	−45.7	68.3	13.1	13,604	56.8	14.2
3	3	**Exxon**	11,153	5.6	9.6	Petroleum	737	−54.1	8.1	6.6	8,548	9.7	8.6
4	4	**Union Carbide**	7,621[d]	−0.4	100.0	Basic chemicals	1033	−17.0	100.0	13.6	7,613	87.2	13.6
5	5	**Monsanto**	5,711	−1.2	63.5	Basic chemicals	624	−32.8	68.6	10.9	4,831	52.3	12.9
6	6	**Hoechst Celanese**	5,499	−2.8	93.5	Basic chemicals	427	−25.9	105.4	7.8	na	na	na
7	8	**General Electric**	5,167[d]	4.8	8.8	Diversified	1017	−3.8	13.2	19.7	7,973	5.2	12.8
8	7	**Occidental Petroleum**	5,040	−2.4	23.2	Petroleum	636	−39.8	23.4	12.6	5,494	27.8	11.6
9	9	**BASF**	4,366	−2.1	81.1	Basic chemicals	na	na	na	na	na	na	na
10	10	**Amoco**	4,087	−4.4	12.9	Petroleum	252	−66.1	6.4	6.2	3,646	11.5	6.9
11	11	**Mobil**	4,084	1.1	7.7	Petroleum	397	−47.1	7.6	9.7	3,265	7.8	12.2
12	12	**Shell Oil**	3,718	−3.0	15.2	Petroleum	519	−44.8	26.6	14.0	3,952	13.9	13.1
13	13	**Eastman Kodak**	3,588	1.9	19.0	Photo equipment	602	−6.4	21.2	16.8	3,952	16.4	15.2
14	15	**W. R. Grace**	3,570	10.8	52.9	Specialty chemicals	431	6.9	77.9	12.1	2,756	44.3	15.6
15	14	**Chevron**	3,325	9.1	8.0	Petroleum	44	−91.7	0.9	1.3	2,622	7.5	1.7
16	17	**Arco Chemical**	2,830	6.3	100.0	Basic chemicals	469	−19.1	100.0	16.6	3,739	100.0	12.5
17	18	**Rohm & Haas**	2,824	6.1	100.0	Basic chemicals	351	22.3	100.0	12.4	2,414	100.0	14.5
18	16	**Allied-Signal**	2,786	−6.9	22.6	Diversified	287	−19.2	39.3	10.3	1,896	18.1	15.1
19	19	**Air Products[e]**	2,614	5.3	90.3	Basic chemicals	441	3.6	108.0	16.9	3,132	80.3	14.1
20	21	**Bayer USA**	2,380	3.6	40.0	Diversified chemicals	91[f]	−24.9	61.2	3.8[f]	na	na	na
21	32	**Rhône-Poulenc**	2,278	42.4	100.0	Specialty chemicals	na	na	na	na	na	na	na
22	22	**American Cyanamid**	2,255	0.6	49.3	Basic chemicals	195	−15.0	62.2	8.7	1,832	36.0	10.7
23	23	**Ashland Oil[e]**	2,245	0.7	25.0	Petroleum	70	−45.3	21.1	3.1	856	16.7	8.2
24	30	**Hercules**	2,193	3.6	68.5	Basic chemicals	167	22.8	69.0	7.6	1,860	50.3	9.0
25	20	**Phillips Petroleum**	2,120	−13.4	15.6	Petroleum	448	−31.3	21.3	21.1	1,797	14.8	24.9
26	42	**Ciba-Geigy**	1,976	10.0	52.0	Specialty chemicals	na	na	na	na	na	na	na
27	24	**Quantum Chemical**	1,959	−6.9	73.8	Basic chemicals	242	−42.7	95.1	12.4	2,235	69.4	10.8
28	25	**B. F. Goodrich**	1,940	−1.9	79.7	Basic chemicals	129	−50.4	85.2	6.7	1,521	64.3	8.5
29	31	**Akzo**	1,893	1.0	100.0	Basic chemicals	152	11.6	100.0	8.0	na	na	na
30	26	**Lyondell Petrochemical**	1,889	19.6	29.1	Petroleum products	na	na	na	na	na	na	na
31	29	**Alcoa**	1,842[d]	5.7	17.2	Nonferrous metals	1319	11.5	121.3	71.6	2,855	25.0	46.2
32	27	**Texaco**	1,723	−5.2	4.1	Petroleum	60	−85.0	2.5	3.5	1,308	5.0	4.6
33	33	**Dow Corning**	1,718	9.1	100.0	Specialty chemicals	171[f]	5.1	100.0	10.0[f]	na	na	na
34	34	**National Starch**	1,670	6.4	100.0	Specialty chemicals	254	12.3	100.0	15.2	1,448	100.0	17.6
35	35	**FMC**	1,624	5.4	43.6	Machinery	192	−15.1	45.4	11.8	1,469	49.6	13.0
36	36	**Ethyl**	1,591	4.7	100.0	Basic chemicals	308	9.0	100.0	19.4	1,383	100.0	22.3
37	28	**±Atochem**	1,540	−13.4	100.0	Basic chemicals	na	na	na	na	na	na	na
38	56	**Degussa**	1,435	61.9	75.3	Specialty chemicals	na	na	na	na	na	na	na
39	45	**Lubrizol**	1,335	18.8	91.9	Specialty chemicals	398	24.1	90.8	29.8	887	79.5	44.9
40	42	**Huntsman Chemical**	1,300	8.3	100.0	Basic chemicals	na	na	na	na	na	na	na
41	40	**Tenneco**	1,298	6.0	8.9	Diversified	167	40.3	11.5	12.9	1,409	7.5	11.9
42	38	**Olin**	1,269	−1.2	49.0	Basic chemicals	45	−74.1	30.6	3.5	945	50.6	4.8
43	39	**Unocal**	1,236	−3.1	10.5	Petroleum	115	−47.0	23.7	9.3	671	6.9	17.1
44	48	**Nalco Chemical**	1,212	13.2	100.0	Specialty chemicals	211	16.3	100.0	17.4	1,037	100.0	20.3
45	44	**PPG Industries**	1,150	−2.1	19.1	Glass products	231	−10.1	25.4	20.1	1,076	17.6	21.5
46	52	**Cabot[e]**	1,107	16.3	66.2	Basic chemicals	147	32.1	89.6	13.3	1,100	63.5	13.4
47	41	**IMC Fertilizer[g]**	1,106	−9.5	100.0	Agrochemicals	171	−33.5	100.0	15.5	1,585	100.0	10.8
48	61	**Great Lakes Chemical**	1,066	34.6	100.0	Specialty chemicals	290	43.7	100.0	27.2	1,406	100.0	20.6
49	67	**Imcera[g]**	1,025	54.7	71.9	Specialty chemicals	104	99.2	92.5	10.2	1,090	51.1	9.6
50	54	**Morton International[g]**	1,021	9.2	62.3	Specialty chemicals	140	−3.4	58.0	13.7	na	na	na

Rank 1990	Rank 1989		Chemical sales 1990 ($-millions)	Change from 1989	Chemical sales as % of total sales	Industry classification	Chemical operating profits[a] ($ millions)	Change from 1989	Chemical operating profits as % of total profits	Operating profit margin[b]	Identifiable chemical assets ($ millions)	Chemical assets as % of total assets	Operating return on chemical assets[c]
51	—	**Reichhold Chemicals**	$1000	na	100.0%	Specialty chemicals	na	na	na	na	na	na	na
52	50	**Solvay America**	997	0%	100.0	Basic chemicals	na	na	na	na	na	na	na
53	51	**Aristech**	974	−2.2	100.0	Basic chemicals	na	na	na	na	na	na	na
54	55	**Farmland Industries**[h]	965	9.2	28.6	Agricultural supplies	$84	−7.0%	52.5%	8.7%	$412	30.4%	20.4%
55	57	**International Flavors**	963	10.7	100.0	Specialty chemicals	243	11.8	100.0	25.3	1129	100.0	21.5
56	53	**Terra Chemicals**	961	1.3	100.0	Agrochemicals	na	na	na	na	na	na	na
57	47	**Georgia Gulf**	932	−15.6	100.0	Basic chemicals	229	−23.6	100.0	24.5	457	100.0	50.1
58	49	**NL Industries**	907	−9.4	100.0	Basic chemicals	251	−18.6	100.0	27.7	1967	100.0	12.8
59	58	**CF Industries**	903	5.5	100.0	Agrochemicals	49	78.5	100.0	5.4	801	100.0	6.1
60	46	**Freeport-McMoRan**	825	−25.3	52.2	Agrochemicals	52	−52.3	17.2	6.3	880	24.5	5.9
61	66	**American Petrofina**	813	22.8	21.1	Petroleum	160	15.7	61.8	19.7	523	18.4	30.6
62	60	**Uniroyal Chemical**	808	0.4	100.0	Specialty chemicals	108	2.4	100.0	13.4	1178	100.0	9.2
63	59	**Engelhard**	807	−0.7	27.4	Diversified	100	3.8	71.0	12.4	874	66.2	11.4
64	65	**H. B. Fuller**[i]	792	5.2	100.0	Specialty chemicals	52	12.8	100.0	6.6	490	100.0	10.6
65	64	**Witco**	769[j]	0.4	47.1	Specialty chemicals	82	363.7	66.9	10.7	477	40.5	17.2
66	62	**Vista Chemicals**[e]	719	−7.7	100.0	Basic chemicals	151	−32.7	100.0	20.9	na	na	na
67	69	**Kerr-McGee**	642	8.4	17.4	Petroleum	123	−1.6	33.8	19.2	658	18.9	18.7
68	72	**Betz Laboratories**	597	15.5	100.0	Specialty chemicals	104	19.0	100.0	17.4	427	100.0	24.4
69	79	**Loctite**	555	17.2	100.0	Specialty chemicals	48	17.0	100.0	8.6	489	100.0	9.7
70	76	**Merck**	551	11.9	7.2	Drugs	68	14.5	2.6	12.3	510	6.4	13.3
71	74	**Pfizer**	548	7.5	8.5	Drugs	29	−26.2	2.5	5.3	418	4.6	6.9
72	77	**Ferro**	513	5.5	45.6	Specialty materials	10	−48.2	14.5	2.0	288	42.0	3.5
73	70	**Sterling Chemical**[e]	506	−12.9	100.0	Basic chemicals	88	−43.4	100.0	17.5	352	100.0	25.1
74	75	**Hoffmann-La Roche**	500	0	20.8	Drugs	na	na	na	na	na	na	na
75	63	**Nova**	489	−27.9	100.0	Basic chemicals	−17	def	100.0	def	221	100.0	def
76	73	**Sun Co.**	486	−4.6	3.7	Petroleum	na	na	na	na	na	na	na
77	68	**GAF**	481	−19.8	52.2	Specialty chemicals	164	−4.4	88.8	34.0	na	na	na
78	—	**Hüls**	465	3.6	100.0	Specialty chemicals	na	na	na	na	na	na	na
79	83	**Union Camp**	460	12.8	16.2	Diversified	22	66.2	6.1	4.9	352	8.0	6.4
80	84	**Sigma-Aldrich**	440	22.6	83.2	Specialty chemicals	104	14.3	94.1	23.5	485	88.7	21.4
81	81	**Dexter**	438	−0.1	48.3	Specialty chemicals	38	23.3	90.7	8.7	280	36.7	13.7
82	78	**Borden Chemicals**	421	−9.7	100.0	Basic chemicals	68	−29.1	100.0	16.1	544	100.0	12.4
83	82	**Vulcan Materials**	409	−4.9	37.0	Nonmetallic minerals	72	−16.2	39.3	17.7	na	na	na
84	85	**Stepan**	390	12.5	100.0	Specialty chemicals	21	83.1	100.0	5.5	247	100.0	8.7
85	87	**Crompton & Knowles**	311	10.7	79.7	Specialty chemicals	43	19.6	72.2	13.9	239	84.5	18.1
86	86	**First Mississippi**[g]	295	−4.1	59.3	Agrochemicals	23	−14.8	97.4	7.8	173	33.9	13.3
87	90	**Calgon Carbon**	285	12.4	100.0	Basic chemicals	62	10.1	100.0	21.9	285	100.0	21.9
88	89	**Petrolite**[k]	283	2.9	94.2	Specialty chemicals	17	−9.4	93.3	5.9	209	82.8	8.0
89	88	**Chemed**	275	−0.9	45.9	Specialty chemicals	23	−38.6	56.3	8.5	139	42.4	16.9
90	92	**Mississippi Chemical**[g]	253	21.1	100.0	Farm cooperative	5	−89.6	100.0	1.9	289	100.0	1.7
91	90	**Georgia-Pacific**	247	−2.4	2.0	Wood products	na	na	na	na	na	na	na
92	94	**Quaker Chemical**	201	10.9	100.0	Specialty chemicals	22	17.6	100.0	10.7	152	100.0	14.1
93	—	**Sequa Corp.**	201	42.4	10.8	Diversified	30	54.4	20.2	14.7	112	5.9	26.5
94	93	**Sherex**	177	−5.9	100.0	Specialty chemicals	na	na	na	na	na	na	na
95	98	**Lawter International**	150	10.3	100.0	Specialty chemicals	28	23.0	100.0	18.5	154	100.0	18.0
96	95	**LeaRonal**[l]	141	−10.5	100.0	Specialty chemicals	14	−10.4	100.0	10.0	81	100.0	17.3
97	99	**Cambrex Corp.**	134	2.0	100.0	Specialty chemicals	4	−32.3	100.0	3.3	na	na	na
98	97	**Eagle-Picher**	123	−19.4	17.5	Diversified	16	7.4	33.3	13.0	76	18.2	21.1
99	—	**Aceto**[g]	122	8.1	100.0	Specialty chemicals	7	−2.4	100.0	5.4	68	100.0	9.6
100	—	**Sybron**	120	na	100.0	Specialty chemicals	na	na	na	na	na	na	na

a Operating income is sales less administrative expenses and cost of sales. b Chemical operating profit as a percentage of sales. c Chemical operating profit as a percentage of identifiable chemical assets. d Chemical sales include significant amounts of nonchemical products. e Fiscal year ended Sept. 30. f Chemical net income. g Fiscal year ended June 30. h Fiscal year ended Aug. 31. i Fiscal year ended Nov. 30. j Does not include all chemical sales. k Fiscal year ended Oct. 31. l Fiscal year ended Feb. 28, 1990.

C&EN's five-way ranking of the Top 100 chemical producers

	Chemical sales			Chemical operating profits			Chemical operating profit margin			Identifiable chemical assets			Return on chemical assets		
		Rank			Rank			Rank			Rank			Rank	
$ Millions	1990	1990	1989	1990	1990	1989	1990	1990	1989	1990	1990	1989	1990	1990	1989
Aceto	$ 122	99	—	$ 7	78	—	5.4%	70	—	$ 68	74	—	9.6%	55	—
Air Products	2,614	19	19	441	13	16	16.9	22	32	3,132	13	11	14.1	33	49
Akzo	1,893	29	31	152	37	45	8.0	59	66	na	—	—	na	—	—
Alcoa	1,842	31	29	1319	3	—	71.6	1	—	2,855	14	—	46.2	2	—
Allied-Signal	2,786	18	16	287	21	20	10.3	49	51	1,896	20	18	15.1	28	34
American Cyanamid	2,255	22	22	195	30	29	8.7	54	55	1,832	22	20	10.7	52	52
American Petrofina	813	61	66	160	36	41	19.7	13	23	523	47	53	30.6	4	8
Amoco	4,087	10	10	252	23	10	6.2	67	31	3,646	11	10	6.9	64	17
Arco Chemical	2,830	16	17	469	11	13	16.6	24	18	3,739	10	13	12.5	44	24
Aristech	974	53	51	na	—	40	na	—	43	na	—	42	na	—	32
Ashland Oil	2,245	23	23	70	53	48	3.1	77	73	856	42	40	8.2	62	52
Atochem	1,540	37	28	na	—	—	na	—	—	na	—	—	na	—	—
BASF	4,366	9	9	na	—	—	na	—	—	na	—	—	na	—	—
Bayer USA	2,380	20	21	na	—	—	na	—	—	na	—	—	na	—	—
Betz Laboratories	597	68	72	104	45	52	17.4	20	33	427	54	57	24.4	8	16
Borden Chemicals	421	82	78	68	54	50	16.1	25	24	544	46	48	12.4	45	40
Cabot	1,107	46	52	147	39	46	13.3	34	53	1,100	34	39	13.4	36	50
Calgon Carbon	285	87	90	62	56	59	21.9	9	15	285	61	63	21.9	10	15
Cambrex Corp.	134	97	99	4	80	78	3.3	76	71	na	—	71	na	—	69
CF Industries	903	59	58	49	60	67	5.4	70	77	801	43	37	6.1	67	72
Chemed	275	89	88	23	69	64	8.5	58	44	139	70	69	16.9	25	11
Chevron	3,325	15	14	44	63	15	1.3	80	37	2,622	16	15	1.7	73	25
Ciba-Geigy	1,976	26	42	na	—	—	na	—	—	na	—	—	na	—	—
Crompton & Knowles	311	85	87	43	64	65	13.9	30	47	239	64	66	18.1	19	26
Degussa	1,435	38	56	na	—	—	na	—	—	na	—	—	na	—	—
Dexter	438	81	81	38	65	66	8.7	54	67	280	62	60	13.7	34	59
Dow Chemical	14,690	2	2	1925	2	1	13.1	35	10	13,604	2	2	14.2	31	9
Dow Corning	1,718	33	33	na	—	—	na	—	—	na	—	—	na	—	—
Du Pont	15,571	1	1	1968	1	2	12.6	38	29	13,788	1	1	14.3	30	22
Eagle-Picher	123	98	97	16	75	75	13.0	36	60	76	73	74	21.1	14	40
Eastman Kodak	3,588	13	13	602	9	12	16.8	23	28	3,952	8	9	15.2	27	30
Engelhard	807	63	59	100	48	59	12.4	40	52	874	41	34	11.4	49	58
Ethyl	1,591	36	36	308	19	24	19.4	15	27	1,383	30	30	22.3	9	12
Exxon	11,153	3	3	737	6	3	6.6	64	40	8,548	3	4	8.6	60	20
Farmland Industries	965	54	55	84	50	51	8.7	54	58	412	56	55	20.4	16	17
Ferro	513	72	77	10	77	73	2.0	78	74	288	60	62	3.5	71	67
First Mississippi	295	86	86	23	69	67	7.8	60	62	173	67	68	13.3	38	46
FMC	1,624	35	35	192	31	33	11.8	45	42	1,469	26	24	13.0	40	45
Freeport-McMoRan	825	60	46	52	58	47	6.3	66	59	880	40	35	5.9	68	56
H. B. Fuller	792	64	65	52	58	62	6.6	64	69	490	49	52	10.6	53	59
GAF	481	77	68	164	35	37	34.0	2	3	na	—	—	na	—	—
General Electric	5,167	7	8	1017	5	6	19.7	13	19	7,973	4	3	12.8	43	52
Georgia Gulf	932	57	47	229	28	22	24.5	7	5	457	53	50	50.1	1	1
Georgia-Pacific	247	91	90	na	—	—	na	—	—	na	—	—	na	—	—
B. F. Goodrich	1,940	28	25	129	41	26	6.7	63	46	1,521	25	22	8.5	61	38
W. R. Grace	3,570	14	15	431	14	18	12.1	44	49	2,756	15	16	15.6	26	44
Great Lakes Chemical	1,066	48	61	290	20	34	27.2	5	9	1,406	29	29	20.6	15	36
Hercules	2,193	24	30	167	33	42	7.6	62	64	1,860	21	25	9.0	58	61
Hoechst Celanese	5,499	6	6	427	15	14	7.8	60	57	na	—	—	na	—	—
Hoffmann-La Roche	500	74	75	na	—	—	na	—	—	na	—	—	na	—	—

	Chemical sales			Chemical operating profits			Chemical operating profit margin			Identifiable chemical assets			Return on chemical assets		
		Rank			Rank			Rank			Rank			Rank	
$ Millions	1990	1990	1989	1990	1990	1989	1990	1990	1989	1990	1990	1989	1990	1990	1989
Hüls	$ 465	78	—	na	—	—	na	—	—	na	—	—	na	—	—
Huntsman Chemical	1300	40	42	na	—	—	na	—	—	na	—	—	na	—	—
IMC Fertilizer	1106	47	41	$ 171	32	27	15.5%	26	20	$1585	24	21	10.8%	51	48
Imcera	1025	49	67	104	45	60	10.2	50	63	1090	35	44	9.6	56	65
International Flavors	963	55	57	243	25	32	25.3	6	8	1129	33	43	21.5	11	7
Kerr-McGee	642	67	69	123	42	43	19.2	16	20	658	45	38	18.7	18	47
Lawter International	150	95	98	28	68	69	18.5	17	35	154	68	70	18.0	20	42
LeaRonal	141	96	95	14	76	74	10.0	51	56	81	72	73	17.3	22	37
Loctite	555	69	79	48	61	55	8.8	57	30	489	50	58	9.7	54	23
Lubrizol	1335	39	45	398	16	21	29.8	3	2	887	39	41	44.9	3	4
Lyondell Petrochemical	1889	30	26	na	—	—	na	—	—	na	—	—	na	—	—
Merck	551	70	76	68	54	58	12.3	43	50	510	48	51	13.3	37	55
Mississippi Chemical	253	90	92	5	79	61	1.9	79	14	289	59	46	1.7	72	64
Mobil	4084	11	11	397	17	9	9.7	52	26	3265	12	12	12.2	46	10
Monsanto	5711	5	5	624	8	8	10.9	46	36	4831	7	7	12.9	41	28
Morton International	1021	50	54	140	40	39	13.7	31	38	na	—	36	na	—	42
Nalco Chemical	1212	44	48	211	29	35	17.4	20	33	1037	37	32	20.3	17	33
National Starch	1670	34	34	254	22	31	15.2	27	41	1448	27	26	17.6	21	38
NL Industries	907	58	49	251	24	25	27.7	4	4	1967	19	—	12.8	42	—
Nova	489	75	63	−17	81	—	def	81	—	221	65	—	def	74	—
Occidental Petroleum	5040	8	7	636	7	4	12.6	38	13	5494	6	6	11.6	48	21
Olin	1269	42	38	45	62	36	3.5	74	45	945	38	33	4.8	69	35
Petrolite	283	88	89	17	74	71	5.9	68	68	209	66	65	8.0	63	61
Pfizer	548	71	74	29	67	63	5.3	72	64	418	55	49	6.9	65	66
Phillips Petroleum	2120	25	20	448	12	11	21.1	10	7	1797	23	23	24.9	7	3
PPG Industries	1150	45	44	231	27	27	20.1	12	16	1076	36	31	21.5	12	13
Quaker Chemical	201	92	94	22	71	69	10.7	47	48	152	69	72	14.1	32	27
Quantum Chemical	1959	27	24	242	26	17	12.4	40	22	2235	18	19	10.8	50	19
Reichhold Chemicals	1000	51	—	na	—	—	na	—	—	na	—	—	na	—	—
Rhône-Poulenc	2278	21	32	na	—	—	na	—	—	na	—	—	na	—	—
Rohm & Haas	2824	17	18	351	18	23	12.4	40	54	2414	17	17	14.5	29	51
Sequa Corp.	201	93	—	30	66	—	14.7	28	—	112	71	—	26.5	5	—
Shell Oil	3718	12	12	519	10	7	14.0	29	11	3952	8	8	13.1	39	14
Sherex	177	94	93	na	—	—	na	—	—	na	—	—	na	—	—
Sigma-Aldrich	440	80	84	104	45	53	23.5	8	12	485	51	54	21.4	13	28
Solvay America	997	52	50	na	—	—	na	—	—	na	—	—	na	—	—
Stepan	390	84	85	21	73	77	5.5	69	75	247	63	64	8.7	59	68
Sterling Chemical	506	73	70	88	49	38	17.5	19	6	352	57	59	25.1	6	2
Sun Co.	486	76	73	na	—	—	na	—	—	na	—	—	na	—	—
Sybron	120	100	—	na	—	—	na	—	—	na	—	—	na	—	—
Tenneco	1298	41	40	167	33	44	12.9	37	60	1409	28	27	11.9	47	61
Terra Chemicals	961	56	53	na	—	—	na	—	—	na	—	—	na	—	—
Texaco	1723	32	27	60	57	19	3.5	74	16	1308	31	28	4.6	70	6
Union Camp	460	79	83	22	71	76	4.9	73	76	352	57	61	6.4	66	70
Union Carbide	7621	4	4	1033	4	5	13.6	32	38	7613	5	5	13.6	35	31
Uniroyal Chemical	808	62	60	108	44	—	13.4	33	—	1178	32	—	9.2	57	—
Unocal	1236	43	39	115	43	56	9.3	53	70	671	44	45	17.1	24	57
Vista Chemicals	719	66	62	151	38	30	20.9	11	1	na	—	47	na	—	5
Vulcan Materials	409	83	82	72	52	54	17.7	18	25	na	—	—	na	—	—
Witco	769	65	64	82	51	72	10.7	47	78	477	52	56	17.2	23	70

Note: Companies giving only net profits are not ranked. There are 81 firms ranked for operating profits and operating profit margins and 74 ranked for chemical assets and return on assets.

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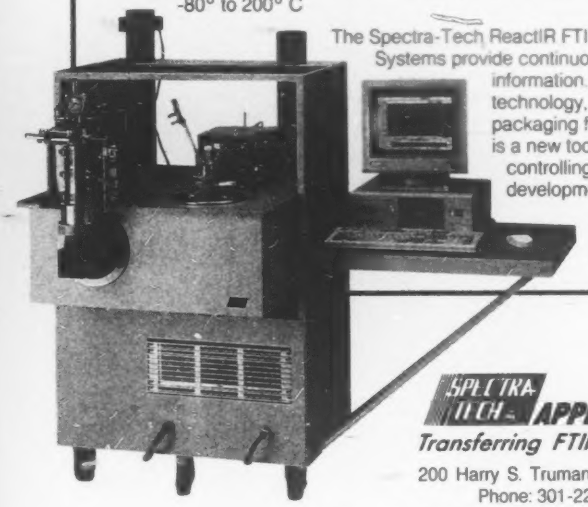

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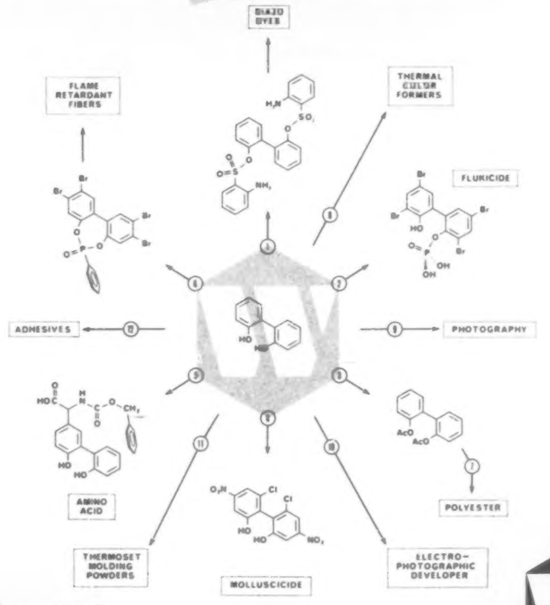

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list, accounting for about 86% of total chemical sales. This is the same percentage that this group showed in the 1989 ranking.

Firms classified as chemical companies accounted for about 41% of total sales, the same percentage as they had in the ranking for 1989. However, the remaining 59% is divided slightly differently. In the rankings for 1990 chemical sales, oil and natural gas companies account for 21% of the total, compared with 23% of the 1989 total; diversified and other firms make up 20%, down from 21%; and foreign-owned firms provide 18% of the total, up from 15%.

This mix has changed considerably in the past five years. Among the companies making up the list in 1985, the 50 largest firms accounted for just 79% of total chemical sales. And among the classifications of companies, the foreign-owned firms have more than doubled their percentage of the total to 18% in 1990 from just 8% in 1985 at the expense of two of the other groups. While the chemical group is up slightly from 39% to 41%, petroleum and gas is down from 26% in 1985 to 21% last year, and diversified and other companies' contribution has fallen from 27% to 20%.

Among the companies included in the ranking of 1990 chemical sales, there are just five firms new to the list—Reichhold Chemicals, now a part of Japan's Dainippon at number 51; Hüls, the U.S. subsidiary of the German company at 78; Sequa Corp., number 93; Aceto at number 99; and Sybron at the 100th position.

Of the five companies that dropped off the list, only one was because of a decline in chemical sales. BP America, the U.S. arm of British Petroleum and the 37th largest chemical producer for 1989, has changed its accounting methods and no longer discloses chemical sales. The U.S. arm of Switzerland's Lonza, which ranked 80th in last year's listing, also would not disclose sales for 1990.

Atlas Powder, which was in the process of being acquired by ICI from Tyler last year and was ranked 71st, has now been fully absorbed by the British chemical giant, which does not disclose U.S. chemical sales.

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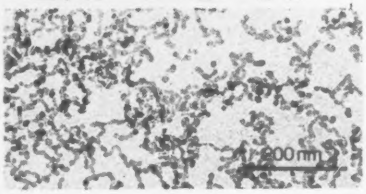

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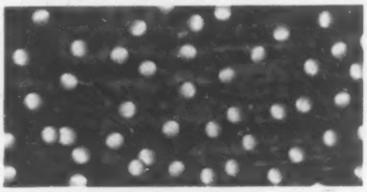

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CIRCLE 26 ON READER SERVICE CARD

Agway, number 100 company in 1989, also no longer discloses chemical sales. Only Nu-West, which was 96th on the listing last year, had a sales decline, which took it off the table.

There is no surprise that the number one company on the list is Du Pont. It was the largest U.S. chemical producer in last year's listing and in fact has held that position as long as C&EN has been ranking the top chemical producers.

Du Pont is followed by Dow Chemical, as it had been in 1989. However, Dow continues to make small gains on Du Pont's top spot and is now less than $1 billion behind the Wilmington, Del.-based giant in chemical sales.

Within the top 10 firms, the companies represented in the 1990 rankings are the same as in 1989. And all have maintained their positions with the exception of General Electric and Occidental Petroleum, which have exchanged positions. This year, General Electric moves up one position to seventh place and Occidental moves down one slot to eighth.

A great deal of movement took place among the Top 100 chemical producers for 1990, with 38 companies improving their rankings over 1989, 20 remaining in the same position, and 37 slipping in the rankings. The remaining five were not included in the listing last year.

The two biggest improvements in rank were by Degussa and Imcera. Degussa moved up 18 places to 38th in 1990. Imcera increased its position the same number of places to 49th from 67 for the ranking in 1989.

Other double-digit improvements were registered by Ciba-Geigy, which jumped 16 places to number 26; Great Lakes Chemical, up 13 places to number 48; Rhône-Poulenc, up 11 positions to number 21; and Loctite, up 10 places to number 69. Of the remaining companies that moved up, four improved six places; two moved up five spots; five improved by four positions; three were up three places; eight improved two places; and 10 moved up one position.

The largest decline in rank was recorded by Freeport-McMoRan, down 14 places to number 60. This was followed by Nova, down 12 places to number 75, and Georgia Gulf, down 10 places to number 57. Three companies dropped nine places; one firm down six; two down five; six off by four; five down by three and five more off by two; and 12 down one spot.

Once again, although C&EN includes all of the companies from which it can get chemical sales figures in its ranking, there are a number of firms that would be included if they were to disclose the results of their chemical operations. Chief among these are ICI and now BP, but the list also includes such publicly held U.S. firms as 3M and Procter & Gamble and some private firms such as J. M. Huber and PQ Corp.

Though sales improved for most of the companies between 1989 and 1990, they were not so fortunate in operating profits, where higher raw material and other costs and lackluster pricing took a considerable toll. Of 81 companies that report operating profits from chemical operations, 46 registered declines between 1989 and 1990.

The number one company in chemical operating profits for 1990 was Du Pont, moving up from number two in 1989. Dow Chemical is number two now, but had been number one in 1989.

Number three in chemical operating profits is Aluminum Co. of America. However, its ranking is tainted by the inclusion of a significant amount of nonchemicals into its reporting category. Union Carbide is number four and General Electric number five.

In operating profit margin (operating profits from chemicals divided by chemical sales), the number one company is Alcoa, followed in order by GAF, Lubrizol, NL Industries, and Great Lakes Chemical.

The top five companies in chemical assets, in order, are Du Pont, Dow, Exxon, General Electric, and Union Carbide. And the top five in operating return on those assets (chemical operating profit as a percentage of identifiable chemical assets) are Georgia Gulf, Alcoa, Lubrizol, American Petrofina, and Sequa Corp. □

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MAY 13, 1991

CHEMICAL & ENGINEERING NEWS

Rubber

Producers expect no growth this year but see upturn in 1992
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CHEMICAL & ENGINEERING
NEWS
MAY 13, 1991

Volume 69, Number 19
CENEAR 69 (19) 1-86
ISSN 0009-2347

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- **David Baltimore abandons defense of former collaborator and paper they coauthored; but his apology is rejected by researcher who challenged paper's validity.** Page 7
- **Office of Technology Assessment finds bovine growth hormone safe for cows and safe in meat and dairy products for humans.** Page 7
- **Possibility of contaminated virus cultures brings new twist to protracted U.S.-French dispute over discovery of HIV virus.** Page 8

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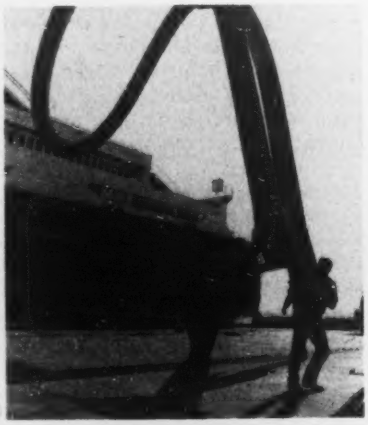
Texas high school team wins first annual National Science Bowl in competition sponsored by Department of Energy and Intel Corp. Foundation. **Page 35**



Product Report

Forecasts for global rubber use indicate 1991 demand likely to be flat, but predict slow, steady rise in consumption next year and through 1995. **Page 37**

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1155—16th St., N.W., Washington, D.C. 20036
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(202) 872-4600; TDD (202) 872-4432
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LETTERS

First reported nanodes

To my knowledge the first electrode with atomic dimensions was reported by B. D. Pendley and H. D. Abruña from Cornell University [*Anal. Chem.*, **62**, 782 (1990)]. They were able to make and perform electrochemical measurements with a platinum ultramicroelectrode of an estimated radius of about 14 A, a width of just a few atoms of the metal.

Unfortunately, both the author of the article, "Electrodes a few atoms wide made at Caltech" (C&EN, Nov. 26, 1990, page 8), and the authors of the article referred to therein [*Science*, **250**, 1118 (1990)] overlooked the contribution reported in *Analytical Chemistry* last April.

Francisco A. Uribe
Los Alamos, N.M.

Polymer science education

The letter by Rudolf Faust (C&EN, March 18, page 3) claims that the polymer group at the University of Lowell was the earliest accredited B.S. program. Polytechnic University (then Polytechnic Institute of Brooklyn) started its Polymer Research Institute under Herman Mark in 1946. I would not step out on a limb and say that was the first one in the nation.

Helmut C. Neumann
Winchester, Va.

Professional esteem

As a graduate student in the last stages of my education, I feel compelled to respond to the attitudes that underlie a disturbing number of letters that appear in the pages of C&EN. Far too often problems are raised (including some that don't exist), but few solutions are suggested. Charles Krutchen's well-written letter (C&EN, Feb. 11, page 38) regarding the environmental movement's effectiveness in eliminating polystyrene foam containers from McDonald's restaurant chain served as the impetus for my response.

From these letters, it seems that chemists (including myself) are very self-conscious and possess low self-esteem when comparing ourselves to other professionals. As individuals, we fret over our diminishing pay scales relative to other professionals such as lawyers and medical doctors, as well at to other "less-learned" professions. Increasing, and more frightening, is the practice of complaining (or even joking) about the actions of ill-informed but powerful public lobby groups.

Please let me state outright that these issues are by no means trivial and they warrant the concern of all chemists. However, they are the symptoms of more serious problems: the lack of well-distributed information, and, unfortunately, our own apathy. The former is the result of the latter and it is up to each of us to correct the problems or put up with the consequences silently.

With regard to pay and professional esteem, I didn't enter chemistry for the money (although it would be nice to receive more), but rather for my love for the science. I didn't become a plumber, automechanic, or an attorney, because I wasn't interested. If my other undergraduate classmates chose not to enter chemistry because of the teaching methods of our professors, insufficient pay, or public recognition, then frankly they weren't all that interested to begin with. Slide shows and more cash would keep them longer, but not forever. It's never been a secret how well we're paid, but I'm certain that better teaching and an improved public image are things that we can and should improve upon.

The concerns of Krutchen, myself, and others are not completely unrelated to the reasons why students choose not to stay in chemistry. It was unfortunate that the polystyrene foam problems arose, but I think that given the magnitude of the solution taken by McDonald's relative to the overall scope of our industries, it may be the cheapest lesson we learn. Yes, there are justified environmental concerns and some outdated practices in the chemical industry that have (and will) come back to haunt us, but the false cry of the uninitiated should not go unheeded. We must be more careful, but more important in the long run, we must tell others about how careful we are, when they're misinformed, and when they're correct.

When you hear the loud minority of emotional but uninformed protesters/activists espouse incorrect or irrelevant facts, contact the source and the reporting media with the correct information. We seem to have enough effort to do so when a rate constant is reported that conflicts with our own work, or to shout when we aren't given credit in a paper's citations for our own work. If their concerns are justified, then work to fix the problem before we all look bad. The public doesn't care which of us is responsible; we're all chemists.

There is a Chinese proverb that states:

Computer analysis (left) of tire and vehicle suspension during actual driving conditions (below) help Goodyear engineers predict stress distribution on tires and auto body

Rubber Demand Is Expected To Grow after 1991

Bruce F. Greek, C&EN Houston

Until the major industrial economies of the world emerge from the effects of the current recession, growth in use of natural and synthetic rubber will remain minuscule. After growing modestly in 1990, global rubber demand this year is forecast to be flat, at 15.7 million metric tons. After 1991, it is expected that consumption of rubber will resume a slow, steady growth.

A slight decline in global consumption of synthetic rubber—10.4 million metric tons from 10.5 million metric tons used in 1990—is forecast for this year by the International Institute of Synthetic Rubber Producers (IISRP), whose statistical committee compiles data annually to predict rubber supply and demand.

Offsetting this decline, consumption of natural rubber will continue to grow globally but only 2%, to total less than 5.3 million metric tons. The net result is a small rise in total rubber consumption of 0.2%. Decreased use of both synthetic and natural rubbers will occur in Eastern Europe (including the Soviet Union) as those economies struggle for improvement, says William E. Tessmer, executive director of IISRP. In other areas of the world, rubber consumption is forecast to increase.

Growth in rubber consumption was modest in 1990, rising about 0.7%, according to IISRP estimates. Last year's rise in synthetic rubber consumption was smaller than that in natural rubber consumption. Synthetic rubber use grew less than 0.4% in 1990, while natural rubber use grew 1.3%.

The slow growth in demand for rubber has confirmed the maturity

Specialty rubbers developed for their special properties

Dozens of specialty rubbers are made around the world in volumes that are small to tiny when compared with the volume of styrene-butadiene rubber or polybutadiene rubber produced. Some of the materials are little more than laboratory curiosities, while others are produced at annual rates above 10,000 metric tons. Most are made in plants capable of making many variations of the basic elastomer, so only producers know the actual volume of these specialty rubbers. Examples of the specialty elastomers include:

Type	special properties
Acrylics	Resist high temperatures, chemicals, solvents, ozone, and light.
Butadiene-, carboxyl-, hydroxyl-, and halogen-terminated polymers	Are liquid to hard glossy polymers, with chemical and heat resistance.
Butadiene block and random copolymers, often with sytrene	Have elastomeric properties without vulcanization.
Epichlorohydrins	Have service temperature range of –65 to 300 °F., low gas permeation and good resistance to chemicals and solvents.
Ethylene copolymers with vinyl acetate, ethyl acrylate	Retain tensile strengths over wide range of temperatures, have good weatherability and good oil resistance.
Fluorinated elastomers, polymers of fluorinated ethylene, propylene, vinylidene	Resist heat, flame, chemicals, and have good weatherability.
Polyethylene-modified chlorine or sulfur and chlorine	Resist ozone, heat, chemicals, oil, and flame, and have operating range of –65 to 300 °F.
Polyisobutylenes	Have good weatherability, good electrical properties, and low gas permeability.
Polyester/polyether polymers	Have service range of –65 to 275°F and high resilience with good resistance to chemicals, oils, and solvents.
Polynorbornenes	Can be highly loaded with oil and fillers; have good dynamic properties and low hardness.
Polyolefin thermoplastic polymers	Have good elastomeric properties without vulcanization; can be reprocessed, and can be modified to allow a wide range of properties.
Propylene oxide-allyl glycidol ether copolymers	Have service range of –77 to 300 °F, excellent resilience and hysteresis, and moderate resistance to oil and solvents.
Silicones and fluorosilicones	Have service range of –150 to 600 °F, excellent resistance to ozone and weather, and good electrical properties.
Sulfide polymers from various organic sulfides	Resist oil and solvents, have good aging characteristics, and low gas permeability.
Urethanes from polyesters, polyethers, and diisocyanates	Are available as either thermoplastic or curable polymers, have high tear and abrasion resistance, good oil, solvent, and ozone resistance, moderate to good low-temperature properties. Cured polymers have good tensile strength and moderate heat resistance.

Source: International Institute of Synthetic Rubber Producers

of this global industry. Growth in demand generally will continue to be low: The IISRP committee forecasts that world demand for rubber will grow only 2.1% annually between 1991 and 1995, with most of the progress occurring after 1991 because of current slowdowns in the automobile and construction industries. By 1995, global use of rubber is expected to reach 17.3 million metric tons, split between synthetic rubber at 11.2 million metric tons and natural rubber at 6.1 million metric tons.

Growth in synthetic rubber use in the future will vary from region to region, according to IISRP data. In North America (Canada and the U.S.), the consumption growth rate will average 2.4% annually between 1991 and 1995, reaching more than 2.8 million metric tons. In Western Europe, Africa, and the Middle East, growth will average 2.0% annually. In Latin America (Mexico and south), synthetic rubber consumption will increase 19% over five years, or 3.5% annually, but from a smaller base of slightly more than 500,000 metric tons. In the Asia/Oceania area, which excludes centrally planned economy countries such as China, the consumption growth rate will average 3.0% annually (spurred in part by increased auto and tire production) and is expected to exceed 2 million metric tons in 1995.

Market share of the various synthetic rubbers will change to a limited extent. Styrene-butadiene rubber (SBR), in the noncentrally planned economies, will have a consumption increase of more than 260,000 metric tons, to greater than 2.9 million metric tons in 1995. This tonnage will account for about 38% of the total use of synthetic rubber, roughly the same market share that SBR had in 1990. Polybutadiene, the second largest elastomer consumed in areas outside the centrally planned economies, will have 16.6% of the market, likely growing fast enough to hold its share in 1995. In 1991, carboxylated SBR latex consumption will exceed polybutadiene use for the first time and should remain in slightly greater demand through 1995.

Other, smaller volume rubbers are experiencing notable growth. Ethylene-propylene elastomers, the growth pacesetter of recent years, will continue to lead with an average annual increase of 4.1% through 1995. Nitrile rubber consumption is expected to hold second place among nonspecialty elastomers, averaging 3.7% annually. Other synthetic rubbers, of which butyl, polychloroprene, and polyisoprene account for a vast majority of the total, will grow more slowly than the larger volume synthetic rubbers.

Thermoplastic elastomers (TPEs) are growing faster than the basic elastomers. They consist of a large number of products considered to be derivatives of other elastomers. The IISRP places TPEs "below the line" as an item in its long-term forecast, says Tessmer. Use of TPEs is projected to expand from 613,000 metric tons in 1989 to 883,000 metric tons in 1995, at an average annual growth rate of 6.3%.

Tires and tire products, traditionally the largest use of rubber, will continue in the lead through 1995 and beyond, according to the current forecast. Tires and tire products are expected to account for more than 61% of total new rubber consumption in 1995. About 51% of all synthetic rubber produced will go into tires and tire products, along with slightly less than 75% of natural rubber production. As in the past, roughly two thirds of SBR and polybutadiene consumption will be in tires.

Rubber cushion for auto drivetrain leaves Goodyear assembly line

Production of automobile, truck and bus, and farm equipment tires outside the former East bloc was about 690 million tires in 1988, according to William W. Barbin, manager, compound technology at Goodyear Technical Center, Akron. In addition, aircraft and various kinds of off-the-road tires were made in relatively small numbers. Of the 690 million tires, about 40% went to markets in North America, 29% to Europe, 24% to Asia and Africa, and 7% to Latin American, Barbin told attendees of the International Rubber Study Group (IRSG) in Ottawa, Canada.

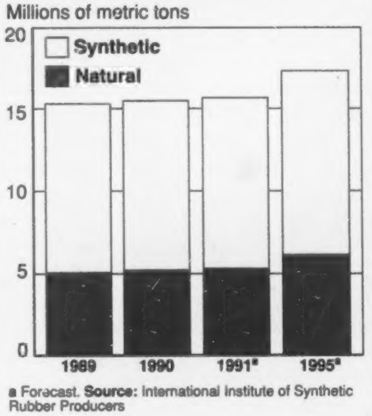
The faster growing types of tires in North America, says Barbin, are those designed for high performance and for all-season operation. High-performance tires require more elastomer in their manufacture because their designs call for larger diameters and lower aspect ratios and because the hard wear such tires usually receive shortens tread life.

The U.S. passenger car tire market becomes increasingly affected by new-vehicle gasoline mileage requirements. Barbin estimates lowered tire-rolling resistance will contribute only 0.5% of an 18% increase expected in the average fleet gas mileages of carmakers. Nevertheless, this potential share in improving average fuel consumption looms as an important factor in winning original equipment markets.

The kind of polymer in the compound of elastomer, carbon black, silica, and other chemicals used to make a tire can have a significant effect on its rolling resistance, says Barbin. To determine this characteristic, the hysteresis of a compound is tested over a range of temperatures. Polymer engineering then is used to produce a best balance between traction and rolling resistance for the tread compound.

As a result, Barbin expects changes in synthetic rubbers will continue. Additional different solution SBRs will come to market, as will numerous new specialty polymers. The halobutyl elastomers likely will be used more and more in tires. Other elastomers—emulsion SBR, nitrile, and polyisoprene—are expected to have stable markets, while ethylene-propylene diene monomer rubber (EPDM) will grow only if it is cost/performance competitive.

Slow growth expected for global rubber use



ª Forecast. **Source:** International Institute of Synthetic Rubber Producers

Tires accounted for 61% of the more than 7 million metric tons of synthetic rubber consumed in 1990, according to estimates of the IISRP. Of the remaining consumption, another 10% went to automobile mechanical goods, such as belts, hoses, and gaskets. This category includes replacement parts, just as consumption of rubber in tires includes replacement tires.

Automotive mechanical goods often are made of specialty elastomers, selected for their abilities to meet such stress conditions as the higher temperatures now encountered in engine compartments—a result of efforts to reduce polluting emissions and increase mileage. This area of synthetic use, because of its size, spurs developmental efforts in new elastomers and on modification of existing elastomers to allow them to be specified for use in automotive mechanical goods.

Another large use of synthetic rubber is in making mechanical goods for nonautomotive applications. These rubber products cover a wide variety of belting (including conveyer belts), of hose for many types of service, and of other fabricated products. About 650,000 metric tons of synthetic rubbers were used in such products last year, almost as much as went into mechanical goods for automotive uses.

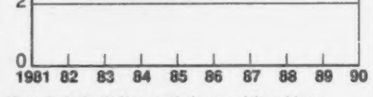
Smaller use areas include modification of various thermoplastics, usually to impart shock resistance; footwear, largely shoe and boot soles; construction, mainly roofing material and pond lining; wire coverings, especially for services where plastic wire covering doesn't perform well; and adhesives of many kinds. As a group that includes other smaller miscellaneous applications, these uses account for more than 20% of synthetic rubber consumption.

Outlook varies widely; some uses continue to have high growth rates while others are declining. The nonautomotive uses are growing faster than the tire and tire product uses, but from a smaller base. And such uses are expected to have less effect on the total rubber demand than will tires, especially if high-performance tire use increases rapidly and if vehicle speeds continue to increase.

SBR is the most widely used synthetic elastomer. As a result, SBR is the elastomer by which all new polymers are judged. In the past, SBR was produced in larger quantities in the U.S. than are produced now. In 1973, SBR's peak year, output was nearly 1.37 million metric tons. At 807,000 metric tons last year, output was off more than 40% from the high of 1973. Yet, that output was well above the production of 692,000 metric tons in 1985, the lowest in recent history.

Available capacity has followed the trend in production decline. At the end of World War II, U.S. capacity to make emulsion SBR was 850,000 metric tons, Terry J. Renninger, president of Firestone Synthetic Rubber & Latex, a division of Bridgestone/Firestone told the IRSG meeting. By 1973, U.S. capacity totaled almost 1.4 million metric tons. Since then, capacity has contracted to 881,000 metric tons, close to the 1945 capacity. The U.S. capacity is close to the 776,000 metric tons of Western Europe and to the 882,000 metric tons of Asia. Africa has one plant with 40,000 metric tons of capacity, and Latin American has about 379,000 metric tons of capacity. That is a capacity total of slightly less than 3 million metric tons. Another 1.8 million metric tons are available in the centrally planned economy countries, Renninger says. And there is 576,500 metric tons of solution SBR capacity outside the centrally planned economies, but no estimate of capacity in those countries is available.

Synthetic rubber capacity is edging up



Note: Includes latices; excludes specialty rubbers.
Source: International Institute of Synthetic Rubber Producers

Outside the centrally planned economies, capacity totals about 3.5 million metric tons, but demand last year was about 2.5 million metric tons, Renninger estimates. Hence, the projection is that competition will remain fierce. Some capacity may be closed. But despite the apparent overcapacity, a significant number of SBR plants, of either emulsion or solution processes, are planned worldwide. Renninger cites IISRP-compiled lists that show plans for one expansion in Western Europe, one in North America, two in Latin America, three in the Middle East/Africa region, and four in Asia/Oceania. If specialized types of SBR, such as latex and TPE are included, the number of new projects rises to 42. It is unlikely that all of those proposed plants will be built, but many will.

Goodyear photo

Worker checks synthetic rubber dock fenders at Texas seaport

Although solution SBR technology allows much greater control of polymer structure than is obtained from emulsion technology, Renninger forecasts that emulsion SBR production will continue well into the next century. Giving reasons, he notes the plants are in place and, in general, are fully depreciated. Worldwide overcapacity will cause continued price pressures that will lead marginal producers to retire some of their capacity. With low margins characteristic of such situations, plant modernization and new product development become more difficult to justify.

Renninger also expects solution technology will become widespread. As it does, producers will emphasize more products designed to meet specific customer needs. Such polymers will be less sensitive to competition, thereby allowing the producers better margins.

The shift toward solution technology for SBR must not be taken too far, Renninger cautions. For example, emulsion technology may produce polymers not easily made when using solution technology. In the solution process as polymerization proceeds, changes in the monomer composition will alter the polymer composition along the chain so that all of the polymer chains will have the same composition. In the emulsion process a similar variation of monomer composition results in polymer chains made with a differing composition, one that is dependent on the monomer composition at the time the specific chain is produced. With the emulsion process, therefore, the result is an in-situ blend of polymer chains of varying composition. Such a blend would be very expensive to make using a solution process, says Renninger.

Another advantage that emulsion technology retains is that many more monomers can be polymerized in it than can be done in solution. If this capability were applied to new concepts unfolding in polymer special end-group solution technology, some unique polymers might be developed that could offer lower rolling resistance in tires. Although the product line of emulsion SBR has changed little over the past 25 years, it would be foolhardy to assume that no new breakthroughs will occur, Renninger points out.

Tires will continue to dominate use of SBR. About 75% of U.S. consumption of SBR currently goes to tires. An additional sizable quantity (about a tenth that of tire use) goes into automotive mechanical goods, for a combined total automotive use of more than 80% of consumption.

Tire use of SBR depends on several properties that provide slightly better cost/performance results than either natural rubber or polybutadiene rubber. (Blends of these elastomers, however, generally are used in tires to obtain the best overall cost/performance/processability). SBR has good abrasion resistance (lower tread wear). It is not so good as polybutadiene but is better than natural rubber. SBR also resists crack and cut growth better than either natural rubber or polybutadiene. A problem of lower tack and low green (unvulcanized) strength with SBR has long been overcome by use of various hydrocarbon resins known as tackifers.

A reversal of the decline in demand for SBR now seems possible, as drivers' demands change. In the 1970s and 1980s, automobile production declined, reducing original equipment demand. At the same time, imports of tires for the replacement market, as well as for imported cars, further reduced U.S.-made tire demand. Downsized cars led to smaller tires containing less elastomer. The shift from bias-ply to radial-ply tires more than doubled tread life and required much larger quantities of natural rubber in the tires' carcass and sidewalls. All of those developments reduced SBR consumption and led to plant closings.

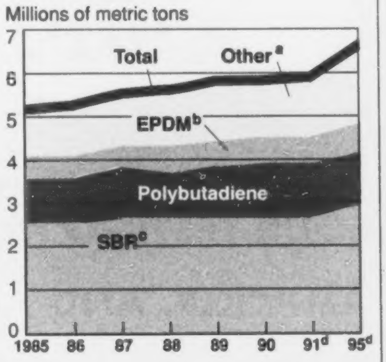
Nontire uses of SBR, at about 25% of consumption, still depend on the automotive industry for about a third of this use category. While a majority of the SBR is used in auto mechanical goods without blending, the trend is toward more blends with EPDM and nitrile rubber. The remainder of SBR uses are mechanical goods such as industrial hose, belting, cable coverings, gaskets, and footwear. Use of SBR in this large miscellaneous group slips slightly each year as performance requirements cause some replacement by other elastomers, especially EPDM. When natural rubber costs significantly less, it also will be substituted for SBR.

Long term, the outlook for SBR appears to be slow growth, probably at an average of 1% annually. Price competition from natural rubber looms as the largest factor limiting SBR growth. Automobile production and imports of tires, especially for passenger cars and light trucks, are next in importance as an influence on growth. Because the solution process provides polymers with more linear configuration and with better control over molecular weight distribution than does the emulsion process, solution SBR could account for most of the future growth as producers work to provide the best possible elastomer for customers.

Natural rubber, the major competitor of SBR, has had erratic growth in U.S. consumption. Since 1980, however, natural rubber consumption has grown every year until 1990, when it declined 3.2% to 839,000 metric tons of both dry rubber and latex, according to data compiled by the Rubber Manufacturers Association (RMA). In 1991, consumption of natural rubber in North America is forecast by IISRP to slip slightly (0.4%), following a 5% decline in 1990. The same reasons for a decline in consumption of SBR will cause the decline in natural rubber.

Consumption of natural rubber mirrors SBR use, with 75% going

SBR share of rubber output slides



Note: Excludes production in centrally planned economy countries (Albania, Bulgaria, China, Czechoslovakia, the former East Germany, Hungary, North Korea, Poland, Romania, U.S.S.R., Yugoslavia, Vietnam) and excludes carboxylated latices. **a** Includes butyl, nitrile, polychloroprene, polyisoprene, and miscellaneous. **b** Ethylene propylene diene monomer rubber. **c** Styrene-butadiene rubber both solid and latex forms. **d** Forecast. **Source:** International Institute of Synthetic Rubber Producers

Uneven growth forecast for rubber demand

	Synthetic rubber				Natural rubber				Total rubber
	Thousands of metric tons			Average annual change, %	Thousands of metric tons			Average annual change, %	Average annual change, %
	1990	1991	1995	1991–95	1990	1991	1995	1991–95	
North America	2,523	2,541	2,842	2.4	909	905	990	1.7	2.2
Western Europe, Africa, Middle East	2,243	2,294	2,471	2.0	1185	1200	1258	1.2	1.7
Asia/Oceania	1,771	1,790	2,052	3.0	1864	1925	2340	4.7	3.9
Latin America	536	553	637	3.5	258	271	314	4.0	3.7
Eastern Europe[a]	2,999	2,848	2,680	–2.2	310	290	400	5.2	–1.4
CEPC—China/Asia[b]	380	403	508	6.0	630	668	843	6.0	6.0
TOTAL	**10,452**	**10,429**	**11,190**	**1.4%**	**5156**	**5259**	**6145**	**3.6%**	**2.1%**

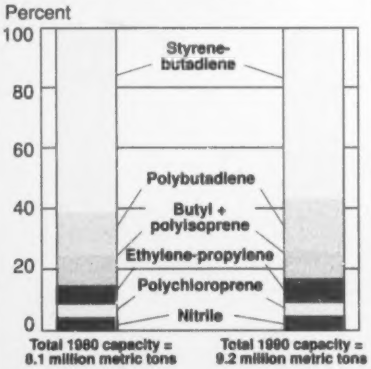
a Includes Albania, Bulgaria, Czechoslovakia, the former East Germany, Hungary, Poland, Romania, U.S.S.R, and Yugoslavia. b Includes the centrally planned economy countries of China, North Korea, and Vietnam. **Source:** International Institute of Synthetic Rubber Producers into tires and retread rubber. The share of natural rubber going into passenger car tires increased over the past decade at the expense of the share going into truck and bus tires because of the rapid shift toward radial-ply design passenger car tires. Natural rubber gets the nod for more use in radial tires because of cost; tire building needs; and flexibility, resilience, and aging stability, all of the properties wanted in tires.

Nontire uses of natural rubber include a 5% share in automotive mechanical goods. Natural rubber often is blended with synthetic elastomers to gain better weathering properties. Nonautomotive mechanical goods account for about 10% of natural rubber consumption and include most of the same applications into which SBR goes.

Natural rubber latex use has been growing rapidly, even while carboxylated and noncarboxylated SBR latices have replaced it in carpet foam. The driving force behind growth of natural rubber latex is in making dipped goods, namely, balloons, surgical and examination gloves, and condoms. The AIDS concern prompted a surge in output of gloves and condoms, which is forecast to continue in the U.S. and spread throughout the world.

Outlook for natural rubber demand depends heavily on pricing, with performance critical in certain applications. Since tires account for about 75% of U.S. consumption, changes in tire demand most directly affect growth. On balance, the forecast growth in use of natural rubber after 1991 will stem from the net effect of such factors as a shift toward slightly larger cars (which will require larger tires, at least until higher fuel economy standards are in place), higher road speeds, net of tire imports over exports, increased construction work to rebuild the country's infrastructure, and tires for large aircraft in operation.

Capacity for smaller volume rubbers grows



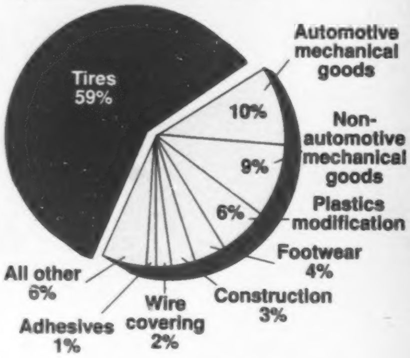
Note: Smaller volume rubbers include latices but exclude specialty rubbers. Capacities do not include those of Albania, Bulgaria, China, Czechoslovakia, the former East Germany, Hungary, North Korea, Poland, Romania, U.S.S.R., Yugoslavia, or Vietnam.
Source: International Institute of Synthetic Rubber Producers

Polybutadiene, another important competitor of SBR, ranks second in output, if carboxylated SBR latex is excluded. This elastomer became commercially available in 1961. Its production rose steadily until the mid-1970s and has been erratic, but generally upward ever since. Output reached its highest level in 1989, at 411,485 metric tons, and declined to 403,388 metric tons in 1990, according to RMA data. Excluding centrally planned economy countries and Eastern Europe, global consumption of polybutadiene is forecast to grow to more than 1.3 million metric tons by 1995, up from less than 1.2 million metric tons in 1991, according to IISRP data. The vast majority of production is solution process; small but unknown quantities of emulsion process polybutadiene are made in various parts of the world.

Because it has good resistance to abrasion, polybutadiene primarily goes into tire treads. Lesser amounts go into carcass and sidewall components, where its flexibility and resilience tend to keep down heat buildup. Wet-skid resistance of polybutadiene is poor, so it is blended with SBR or natural rubber for use in a compromise performance situation.

At about 1.5% annually after this year, the outlook for growth in polybutadiene demand for use in tires calls for only a slightly better performance than will occur for SBR. The relatively low growth track for polybutadiene and SBR will be caused by the same tire-related factors—small increases in tire production, slightly larger tires for increasing numbers of luxury and performance cars, and the continuing shift of truck and bus tires toward the radial-ply design.

Tires dominate global synthetic rubber use



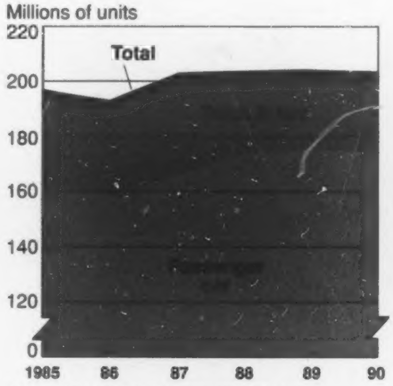
1990 consumption = 7.1 million metric tons

Source: International Institute of Synthetic Rubber Producers

The future impact on polybutadiene by solution process SBR and the more recently developed polymers, such as 1,2-butadiene, is less certain. (Conventional polybutadiene uses the 1,3-butadiene monomer.) Solution SBR could partly replace polybutadiene in tread rubbers. Tests show it provides less tread wear, better skid resistance, and lower rolling resistance. If a significant shift in tread elastomer composition develops, growth for conventional polybutadiene could fall from the current forecast rates.

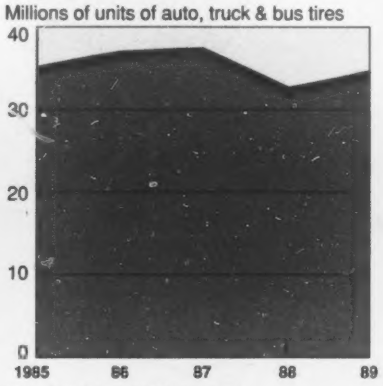
Nontire uses of polybutadiene fall into two categories. About 20% of U.S. consumption goes to modify plastics, such as polystyrene and acrylonitrile-butadiene-styrene (ABS) resins, to give improved impact resistance. There are many variations in how the elastomers are made (depending on their effects on the desired properties in the modified polymer), such as composition of the plastics, and desired properties of the polybutadiene used. Sometimes, the modified resins are alloyed with other plastic resins for specialized applications.

A small amount of polybutadiene goes into various kinds of mechanical goods, some of which are used in the automotive industry. These mechanical goods are similar in form to those made by using other elastomers. Examples are belts of various kinds, hoses, gaskets, seals, and wire covering. An exception is the



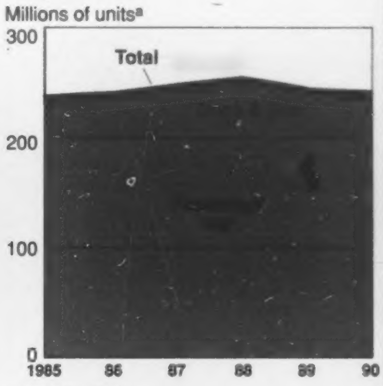
Tire output growth on hold . . .

Source: Rubber Manufacturers Association



. . . as imports less exports increase . . .

Source: Department of Commerce



. . . pushing down U.S. tire shipments

[a] Excludes exports.
Source: Rubber Manufacturers Association

centers for golf balls, which is a small use. Growth in these mechanical goods is expected to be slow and, because these uses are so small, will have a negligible effect on total consumption.

When commercial production of EPDM blossomed, some of its proponents claimed it could be a serious competitor in the tire elastomer market, possibly replacing other synthetic elastomers. While its use as a major tire rubber didn't work out, EPDM has had its uses broadened rapidly and has become a major-volume synthetic elastomer, ranking third in U.S. production. In the past, demand for EPDM became erratic because of the effects of recessions. Demand growth increased at an average annual rate of about 4% during the 1980s. Output in 1990 slipped to 256,000 metric tons, the second minor drop since the peak production year of 1988 when it reached 263,000 metric tons.

Production curtailments, as a result of maintenance and other plant interruptions and ethylene supply limitations, had some impact on EPDM output beginning late in 1988 and lasting until early 1990. Several capacity additions were made in 1989 and 1990, as ethylene supply improved, and more capacity will be available at midyear. In June, Uniroyal Chemical will complete its latest round of expansion at its plant in Geismar, La., to bring the total capacity at that site to about 90,000 metric tons per year. This third production unit at Geismar comes on stream more than 25 years after initial production began in a single, smaller unit that has since been debottlenecked several times.

By midyear, U.S. capacity for EPDM elastomers will be about 325,000 metric tons. Additional capacity at the plant sites of some companies produces ethylene-propylene copolymers. These elastomers account for 10 to 20% of output, estimates an industry source. If demand for EPDM grows very slowly, similar to demand growth for other synthetic elastomers this year, output could hold at about 260,000 metric tons, allowing the in-place capacity to be operated in the 80 to 85% range.

After acknowledging a supply problem for EPDM in 1989 and 1990, Daniel A. Shantz, business manager for EPDM elastomers at Uniroyal Chemical, says no supply tightness will occur for at least two years and probably not for four. Growth in consumption of some uses of EPDM will be quite large, as high as 7% annually, when compared with other tire elastomers. The overall growth will vary between 3 and 5% through 1995.

Tires accounted for less than 3% of EPDM consumption last year, with the rubber going mostly into white strips and raised white letters on tire sidewalls and to use as a blend with butyl elastomers in tubes. Other automotive uses, 17% of total use, went to mechanical goods, hoses, weather stripping, gaskets and seals, and other parts. Many of these products are blends of EPDM and thermoplastic elastomers, says John R. Johnson, Uniroyal Chemical's plastics products development manager. Some of the newer applications of blends are with thermoplastic olefins in the covers for bumpers and with thermoplastic vulcanates for wire coverings.

Those uses in mechanical goods continue to expand use of EPDM in blends because of cost/performance developments, says Johnson. Fabrication advantages help, by allowing fast injection molding and rapid curing to give high part production rates.

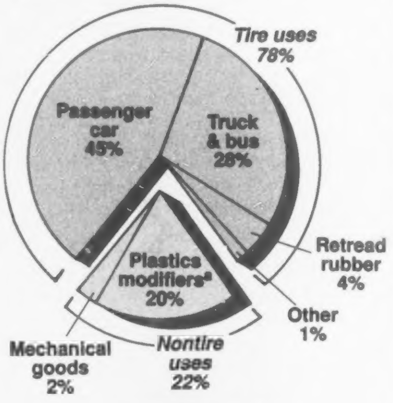
Future developments could carry over to other uses. For example, EPDM can be blended with engineering resins, such as nylons, for a wide variety of applications, Johnson points out. Other blends could include polycarbonates and polyesters.

It's the nonautomotive uses of EPDM that are growing fastest, says Uniroyal's Shantz. Single-ply roofing may be maturing, but after the construction slump of this year is over, this use could grow 6 to 7% annually, he forecasts. As the largest single use of EPDM, roofing will take about 50,000 metric tons this year, he estimates. By 1995, this use could require about 65,000 metric tons of EPDM. Competition from other forms of single-ply roofing limits the growth of EPDM in this use. The major competitors are polyvinyl chloride and other thermoplastics, and asphalts that are modified by styrene block copolymers or by the atactic form of polypropylene. These modified asphalts are impregnated on fiberglass or polyester fabrics to make roofing material. In this use, EPDM dominates but is less than two thirds of the total.

Other important end uses of EPDM include wire and cable insulation, hose (other than for automobiles), components for both household and institutional appliances, sheet materials for such uses as pond liners, and many kinds of gaskets and seals.

A major use of the ethylene-propylene copolymers is in viscosity index additives that are designed to improve the viscosity of lubricating oils as temperatures change. This use of these elastomers is generally considered to be outside of the usual automotive categories involving tires and mechanical goods. The competition from styrene block copolymers and polymethyl methacrylates, does not, because of their cost, eclipse ethylene-propylene copolymers as the greatest use. Growth in this use is promoted by having more vehicles in operation and by a current trend toward higher quality lubricating oils for smaller engines. Such engines are stressed more for increased output. Growth is offset by the trend toward longer intervals between oil changes for newer cars and more use of partially or entirely synthetic oils.

Bulk of polybutadiene goes to tires



1990 consumption = 365,000 metric tons

a To give impact resistance to polystyrene and acrylonitrile-butadiene-styrene resins.
Source: C&EN estimates

Exports account for a large share of U.S. production of EPDM, more than 28% last year, when exports rose to almost 73,500 metric tons, according to RMA statistics. Imports declined drastically in 1990. They dropped from more than 32,000 metric tons to more than 19,000 metric tons last year. The surge in imports of EPDM occurred in 1988 and 1989 when U.S. output was restricted. Exports are expected to continue to rise this year, especially to Europe and the Far East, says Shantz.

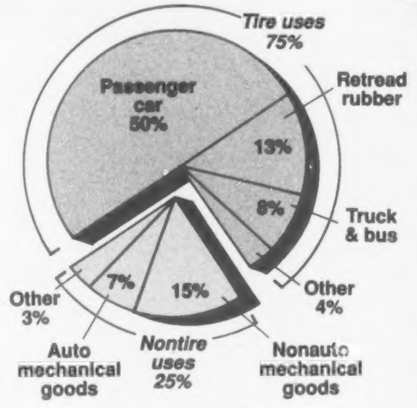
Nitrile elastomers are the only other rubber with production data broken out by the RMA. Last year, production of the various nitrile elastomers was more than 56,200 metric tons. Exports exceeded imports slightly, apparently making consumption about 53,500 metric tons. The peak year for nitrile production was 1974, when the total of dry and latex forms was almost 88,000 metric tons. Global consumption of nitrile elastomers and latex, outside the centrally planned economy countries, will total 249,000 metric tons and will rise to 290,000 metric tons by 1995, according to IISRP.

Both U.S. and world capacity to make nitrile elastomers is more than sufficient to meet demand, says Vincent P. Rooney, business manager for nitrile elastomers at Uniroyal Chemicals. Demand has fallen slowly over the past 15 years because of downsizing of cars, the rise in imported cars, and competition from specialty elastomers, he notes.

Capacity for some U.S. producers is flexible because it is a part of the design of SBR plants. Polymerization by the emulsion process is quite similar to the process for SBR. As a result of flexible capacities, output could be adjusted to meet needs should a possible resurgence occur in demand for nitrile rubbers.

Nitrile's high resistance to hydrocarbons over a wide temperature range is what prompted its first commercial production prior to World War II. A higher concentration of acrylonitrile (the comonomer is butadiene) generally improves this resistance, while lower concentrations produce elastomers with better resilience.

Tires account for 75% of U.S. use of SBR



1990 consumption = 652,000 metric tons

Source: C&EN estimates

Because of nitrile's oil resisting properties, automotive mechanical goods account for more than half of nitrile's consumption, including some use as wire and cable insulation and for impact modification of polyvinyl chloride and ABS resins. These modified resins go into automobile body parts, such as weather stripping, insulation, and kick panels. Nonautomotive uses cover a wide variety of products. Mechanical goods for oil-well drilling and production equipment use more than 10% of consumption, says Rooney.

After this year, growth in demand for nitrile elastomers will be in the 2 to 3% range in the U.S. and in the 4 to 5% range on a global basis, Rooney says. Automotive uses are expected to grow slowly because of competition from other elastomers. Most of the remaining uses will reflect the growth in gross national product.

Numerous other elastomers are produced in varying quantities, with production reported only as a total because of disclosure problems. Some of these, such as butyl, polyisoprene, polychloroprene (neoprene), silicone, and polyurethane elastomers, are produced in large quantities. Production of this group in 1990 was more than 546,000 metric tons, off substantially from the 647,000 metric tons produced in 1989, according to RMA data. Global consumption, excluding the centrally planned economy countries, is forecast to be 1.2 million metric tons this year, according to IISRP. Growth on a global basis will be higher than for SBR because rising performance expectations lead to more demand for the specialty elastomers.

Many of these other elastomers have special niches which consume large shares of total use. For example, butyl elastomers, including the halogenated butyls, go mainly into tire carcass inner liners and tubes because of the elastomers' air impermeability. Polychloroprene elastomers, noted for their resilience and resistance to ozone and weathering, go almost entirely into mechanical goods. Polyisoprene most nearly duplicates natural rubber, so it competes on price, quality, and uniformity for the same tire and nontire uses as natural rubber.

Another large-volume rubber—carboxylated SBR latex—had production of more than 465,000 metric tons in 1990, according to data compiled by the consulting firm Ernst & Young for the Committee on Resin Statistics of the Society of the Plastics Industry. Noncarboxylated SBR latex is included with SBR data by RMA. IISRP estimates 1991 consumption of carboxylated SBR by Eastern Europe and China, North Korea, and Vietnam to be about 1.2 million metric tons.

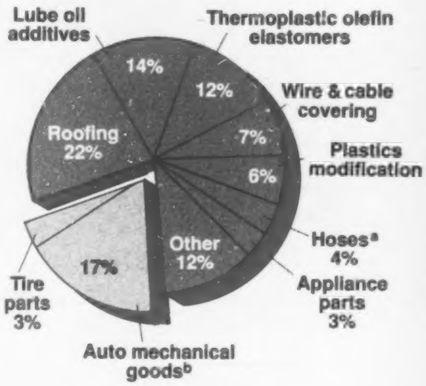
About half of the carboxylated SBR latex goes for coatings of paper, particularly those which are heavily pigmented for glossy printing uses. Paper coating uses are forecast to continue to grow at above the gross national product rate. Consumers have a limited ability to switch to a competitor, polyvinyl acetate, based on prices.

More than a third of this latex consumption goes into carpet backing as a laminating adhesive to hold the fiber tufts to polypropylene or to jute backing. It also is used as backing material in unitary-back carpets. Growth in SBR latex will be affected by technological improvements that will reduce the amount of latex needed per unit area of carpet and by increases in home and commercial building that will increase demand for carpet.

A large number of specialty elastomers are used commercially. Data are not available on their individual production and consumption, either because of the small size or because some may not be included in all the other categories by either RMA or the U.S. Department of Commerce. Some of these specialty elastomers are consumed, but not produced, in the U.S. Imports account for their supply, sometimes less than 1 million lb per year.

Some of the specialty elastomers are made and consumed in greater quantities than are nitrile elastomers. For example, polyurethane elastomers likely were consumed at nearly 150,000 metric tons last year because automotive use boomed as carmakers worked to reduce weights of autos and to improve trim components. Consumption of silicone elastomers is estimated to have reached 50,000 metric tons last year. The styrenic thermoplastic elastomers seems to have neared 150,000 metric tons consumption last year. In contrast, polynorbornene elastomers and propylene oxide-based elastomers each had less than 1 million lb, or under 500 metric tons, consumed in the U.S. last year.

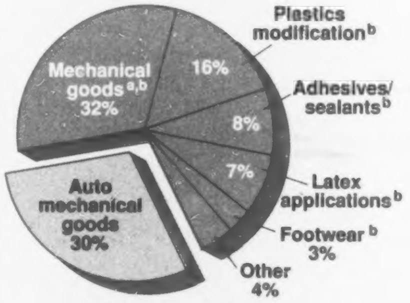
Nonauto uses dominate EPDM consumption



1990 consumption = 196,000 metric tons

Note: EPDM = ethylene propylene diene monomer rubber. a Excludes automotive hoses. b Includes hoses, weather stripping, window seals, and bumper covers. **Source:** C&EN estimates

Low-volume nitrile goes to diverse uses



1990 consumption = 54,000 metric tons

a For industrial, mining, and oil-field applications, and weather stripping. b Nonautomotive use. **Source:** C&EN estimates

Polyurethane elastomers and raw materials are available from several suppliers, some of whom specialize in areas such as microcellular, cast, and millable gum products plus thermoplastic elastomers. A wide range of fabricated products are made of polyurethane elastomers.

Reaction injection molding (RIM) technology is used to produce more than half of the products made from polyurethane elastomer. It is likely the technology will take a growing share of the total because of rapid demand growth in the automotive industry. Nearly all of the automotive consumption is in body parts, particularly bumpers and related trim parts and window frames. Growth in the automotive field could be accelerated if structural reaction injection molding (SRIM), involving fiber reinforcements, becomes a high-speed process, permitting larger body parts to be made. There is competition from other plastic materials based on unsaturated polyesters, for example. Growth in these uses will be cyclical, depending on public acceptance of plastic auto body parts and on automakers' views of costs of such parts. Overall, the growth could range between 3 and 5% annually in the 1990s.

Other RIM products are made for uses outside the automotive industry, such as in office machines, sporting goods, furniture, and other consumer products. Heat shields for copy machines and satellite dishes are SRIM products. Acceptance of RIM urethane elastomers outside the automotive industry requires much technical service by suppliers. Once accepted, however, the use grows rapidly. Outside the automotive industry, these uses of urethane elastomers could grow 5 to 7% annually.

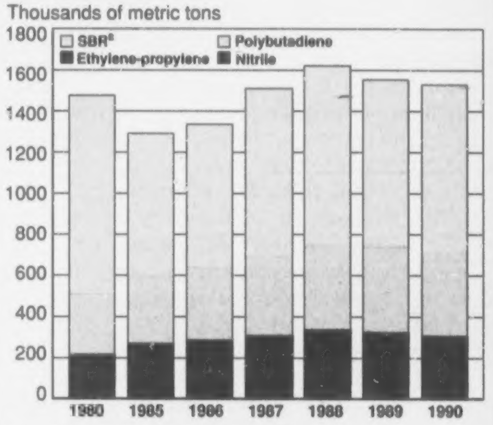
The other forms of urethane elastomers go into more specialized uses. Non-RIM microcellular material goes mainly into high-performance soles for military and sporting boots, the growth of which will be low. Cast elastomers go into many kinds of industrial wheels, electronic product encapsulation, and mechanical goods. Growth of cast materials will depend on industrial and mining growth and is forecast to be low. Millable gums are difficult to process so are used in small quantities in industrial uses where toughness is desired. TPEs account for less than a quarter of polyurethane elastomers. They go into automotive mechanical goods, hoses, adhesives, recreational products, and many other consumer products. These elastomers face competition from plastics and other rubbers, so their growth is forecast at about GNP growth.

Output of silicone elastomers totaled almost 52,000 metric tons in 1989, according to the estimate of the U.S. International Trade Commission. This reported production could be high because fillers and reinforcing agents may have been included. The term silicone elastomers includes fluorosilicones as well as various hydrocarbon-substituted forms. The same plants are used to make silicone fluids and resins as well as elastomers, so capacity is quite flexible.

About two thirds of these elastomers are cured at room temperature; the remainder require heat. Although silicone elastomers have high resistance to hydrocarbons, ozone, and weathering, they have low strength. Therefore, compounding is critical in most applications; compounding technology combines art and science to produce numerous proprietary elastomers.

Almost half of the heat-cured types of silicone elastomers go into automotive applications, say Kevin M. Byrne, business manager for heat-cured rubbers at General Electric's Silicone Products Division. Another 25% goes to wire and cable covering other than for automotive use. Medical applications, largely tubing, are about 10%.

Little growth in U.S. rubber output in past decade



a Styrene-butadiene rubber; polymer and oil.
Source: Rubber Manufacturers Association

Growth should be 5 to 7% annually, says Byrne. The Clean Air Act will spur automotive uses. Parts for various durable items also will grow once the recession is over. Blends with other materials hold significant potential because they are a means of reducing costs while maintaining performance.

Sealants and adhesives of many kinds account for about half of silicone elastomer consumption. Many of these uses are in the construction industry where adhesives may be used with extruded silicone elastomers. Other uses are in various electronic and electrical devices either as adhesives or as encapsulating and cushioning agents. These uses are forecast to account for most of the increased future demand.

Many kinds of TPEs are commercially available. Global demand outside the centrally planned economy countries will reach nearly 700,000 metric tons in 1991, according to IISRP. Strong growth in TPEs is also forecast, with consumption at more than 880,000 metric tons in 1995. Consumption in Canada and the U.S. in 1991 will be 278,000 metric tons, about 10% of the total.

A major share of TPEs are various block copolymers of styrene. Butadiene, isoprene, butylene, and ethylene are examples of the comonomers. The special attraction of these elastomers lies in the ability to process them as plastics yet retain properties of vulcanized elastomers and in the ability to reprocess them as scrap.

Growth of TPEs has been high and will continue so, if forecasts prove accurate. New polymers and new entrants into the TPE field should keep growth steady. The use pattern also may be changed in the future, as new products come to market, but current major uses will grow substantially.

Between 40 and 50% of consumption is in adhesives and sealants. Much is used on packaging tape and on labels and as a bonding agent between different kinds of plastics. Modifiers for plastics and asphalts take another one third of consumption. TPEs add impact resistance to plastics. The modified asphalts are applied to fabrics and used as roofing materials in competition with EPDM and polyvinyl chloride. Many other products are made from TPEs, such as footwear, vicosity index improvers, parts for toys, housewares, automobile parts, wire and cable coverings, and medical device components. Growth should be well above the rate of other large-volume elastomers during the 1990s.

TPEs represent a faster changing part of the rubber or elastomers industry, notwithstanding that the whole industry is changing. Old-line elastomers are being modified to meet the new cost/performance demands from changing consumer products. By the year 2000, this industry will have changed more than during the 1980s, says IISRP's Tessmer. □

MAY 20 1991

CHEMICAL & ENGINEERING

NEWS

Chemical companies' first-quarter earnings show mixed results
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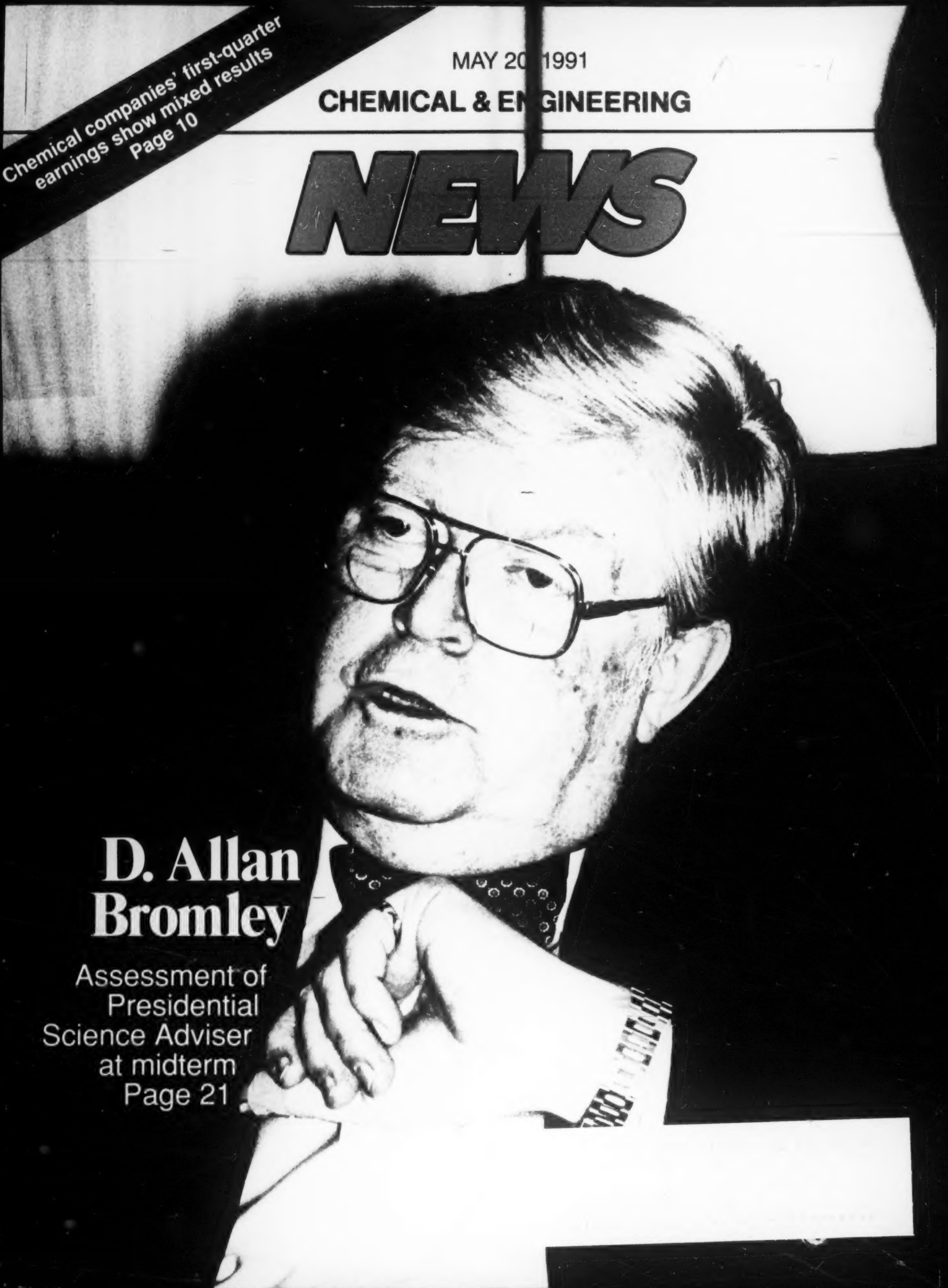

D. Allan Bromley

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Volume 69, Number 20
CENEAR 69 (20) 1–56
ISSN 0009-2347

CHEMICAL & ENGINEERING NEWS

MAY 20, 1991

News of the Week

- **President Bush pushes for global ban on chemical arms by next May and, in policy shift, says U.S. will destroy all its stocks and production facilities within 10 years of treaty's going into force.** Page 4
- **National Transportation Safety Board approves staff report recommending tighter rules for shipping chemicals by rail as well as better training for rail workers and emergency personnel.** Page 5
- **FMC Corp. and EPA have negotiated an agreement to phase out use of granular forms of FMC's pesticide Furadan, except for certain areas and uses, because of risk to birds.** Page 5
- **Texas Eastern to start first pipeline transport of methyl *tert*-butyl ether, as compliance with Clean Air Act pushes up demand.** Page 6
- **Advisory panel appointed to study FDA calls for major reforms, says agency is buried within the federal bureaucracy and suffers from chronic lack of leadership.** Page 6

Cover: Photo by C&EN's Pamela Zurer

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Rising costs are pushing ethylene producers to be more selective in their choice of feedstock. Page 15

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Congress' spring agenda features bills on trade, energy, and agency budget authorizations. Page 18

Sustainable farming methods, minimal use of chemical fertilizers and pesticides called for by UN group. Page 20

Science/Technology

Structures of two components that modulate human immune system have been determined in achievements that may lead to new immunosuppressant drugs. Page 25

How to improve public perception of chemistry is discussed by multinational group of chemical society presidents and officials meeting in London. Page 27

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
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Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Minorities in science

The article on minorities in science (C&EN, April 15, page 20) can only be described as first class. It sweeps away the myths. As you point out, the truth is that the chief determiner of success in school is family background—mostly wealth. This has been amply demonstrated by research. As a very good example, see the article by Schiff et al. in *Science* [**200,** 1503 (1978)].

We can write new texts, train our teachers better, revise courses, etc., but all these will be of little use until we tackle the basic problem: poverty. Specifically, many minorities in the U.S. have very low incomes. (Half of all black children live below the poverty level.) Until we raise the income of all those people to a decent level they will be drastically underrepresented in science, or any profession requiring higher education.

To borrow a quote from Pogo, "We have met the enemy, and they is us."

R. Thomas Myers
Professor of Chemistry Emeritus
Kent State University

Prime source of CO_2

I read with some interest the article (C&EN, April 1, page 7) on possible causes for the greenhouse effect and unwanted emissions into Earth's atmosphere. I am sure a great deal of work has gone into estimating various industrial effluents and automobile emissions. I wonder why in all of the articles I read on the subject that there is no mention of one of the prime sources of carbon dioxide, and that is human respiration.

Just a quick calculation, based on the starting point of 200 cc per minute of carbon dioxide released by each human (at resting metabolism, according to a physiology book), this computes out to be a couple billion metric tons a year. If to the humans you add animal respiration, then that probably doubles the number, which equals or exceeds the estimates from industrial and transportation sources.

I do not want to minimize the efforts under way to decrease the amount of greenhouse gases being released into the atmosphere. Furthermore, as I said in my Otto C. Schmidt Memorial Lecture at Rose-Hulman Institute of Technology a couple of years ago, I decry the use of petroleum and other natural resources as energy producers, since their long-term value as a chemical raw material will be much more important to civilized man than the energy they produce.

However, I am suggesting putting everything into perspective. I think it is important to be aware of all of the sources adding carbon dioxide to the atmosphere, and I just wonder why no one mentions metabolism as an important source?

Henry L. Richter
Arcadia, Calif.

Supply and demand

In reading Joseph Faucher's comments (C&EN, March 25, page 3) regarding shortening the time to a Ph.D., I felt that, although he addresses an important issue, he may be missing an important point. We live in an oversupply and demand society, and it is no wonder that professional training follows the dictates of this philosophy. This approach serves the government and industry well. The more qualified people that are available in the marketplace, the easier the selection process and more moderate the remuneration.

Industry, government, and academic research institutions thrive on highly talented, cheap labor (or graduate students) to do the bulk of the research. Shortening the time to the Ph.D. would adversely affect the cost/benefits derived from such a well-established, effective system! We often do not give undergraduate students enough credit for having common sense about career choices, but they may very well be way ahead of us. The cold reality is that academia does not promise financial success following the completion of a degree program. As an old vaudevillian once said, "You pay your fee and you take your chances."

Stephen A. Davis
Hollywood, Fla.

Common meaning of chemical

None of the recent letters on the meaning of the word chemical have noted that in common usage a chemical is a substance that is understood or described in terms of its formula, molecular properties, and reactivity. When something (perhaps the same thing) is not understood or described in terms of its formula, properties, or reactivity, it is not a chemical. Water is a chemical when we predict that decomposing it

Chemical Earnings Downward Drift Continues in First Quarter

Recession is big factor; still there are some encouraging signs, with earnings and profitability up over fourth quarter of last year

William J. Storck,
C&EN Northeast News Bureau

Earnings at major chemical companies in the first quarter continued to decline on average, but there were some sparks of hope within C&EN's sample of 30 firms. Meanwhile, earnings were up at major oil companies that also produce chemicals and at pharmaceutical companies, but earnings fell at diversified firms with significant chemical operations.

Earnings for the 30 major chemical firms fell an average of 8% from the same period last year—a much better earnings performance than that of the 11 diversified manufacturers, whose earnings fell an average 26%. For the 13 oil companies surveyed, earnings were up 40% from first-quarter 1990, while at nine drug companies, earnings rose an average 50%.

The 8% earnings decline for the 30 chemical firms brought their total earnings down to almost $1.39 billion. Sales for the companies totaled almost $21.8 billion, an increase, however, of 3% over the same period in 1990. Thus, the average profit margin for the 30 companies dropped to 6.4% in the first quarter of this year from 7.1% in the first three months of last year.

Diverse factors affected the chemical industry in the first quarter. The war in the Persian Gulf, the recessionary economy at home and slowing of overseas markets, a slight downturn in raw material costs, and increasing pressure on selling prices are just a few.

The prelude to the Persian Gulf War had created uncertainty in world markets and caused raw material costs, especially for basic petrochemicals, to climb. However, the war itself eased some of those pressures—especially raw material costs, which quickly settled at or below what they had been before the Iraqi invasion of Kuwait. These costs have since risen slightly, but to nowhere near what they were before the war began.

One of the worrisome factors still affecting the industry, however, is the recession, both in the U.S. and overseas. Last year, in spite of the slowing U.S. economy, domestic producers were still able to keep demand up through exports. Industry sources say that this export market is indeed slowing considerably, especially for plastics where it had been strong. The result may well be continued declining capacity utilization, and thus declining profit margins.

As a result of declining demand and some inventory retrenchment, production went virtually nowhere in the first quarter. Production of chemicals and allied products as reported by the Federal Reserve Board increased less than 1% in the January through March period, compared with the same three months a year ago.

However, prices of chemicals and allied products moved up briskly, averaging 5.0% above the first quarter of 1990, according to the Labor Department. This is a slight easing

Chemical industry leaders for first-quarter 1991

Sales				Earnings[a]			Profitability		
Rank 1991		$ Millions	Rank 1990		$ Millions	Rank 1990		Earnings as a % of sales	Rank 1990
1	Dow Chemical	$4948.0	1	Dow Chemical	$365.0	1	International Flavors	17.4%	1
2	Monsanto	2223.0	2	Monsanto	166.0	2	Great Lakes Chemical	12.1	3
3	Union Carbide	1857.0	3	American Cyanamid	104.8	3	Betz Laboratories	11.2	6
4	W. R. Grace	1643.0	4	Union Carbide	101.0	4	Loctite	11.0	5
5	American Cyanamid	1312.8	5	Air Products	62.0	6	Nalco Chemical	10.8	6
6	Hercules	768.4	6	Ethyl	52.9	8	Vista Chcmical	9.5	9
7	Air Products	754.7	7	Arco Chemical	52.0	5	Lubrizol	9.5	14
8	Quantum Chemical	740.2	10	International Flavors	47.0	9	Air Products	8.2	16
9	Arco Chemical	682.0	9	Rohm & Haas	41.3	7	Ethyl	8.1	11
10	Rohm & Haas	679.7	8	Morton International	40.3	10	American Cyanamid	8.0	13

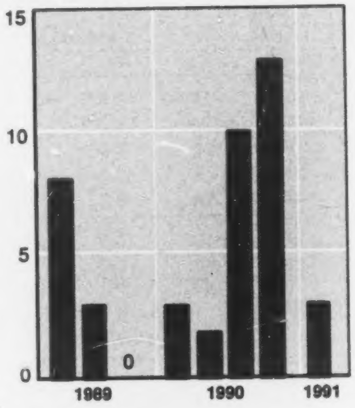
Note: Based on 30 chemical companies listed on page 12. a After taxes.

Chemical industry 1991 first-quarter results

- Sales were up just 3%
- Earnings fell 8%
- Profitability down to 6.4%
- Production was about flat
- Prices increased 5%

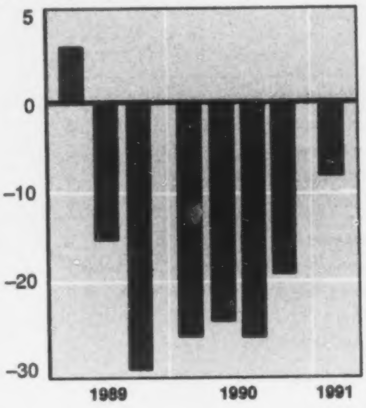
Sales

% change from year-earlier quarter



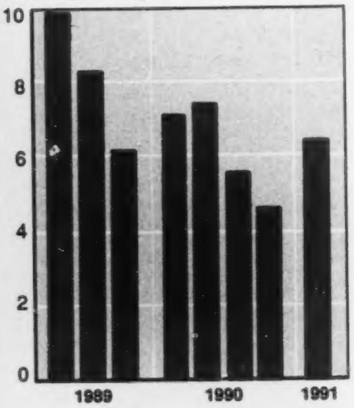
Earnings

% change from year-earlier quarter



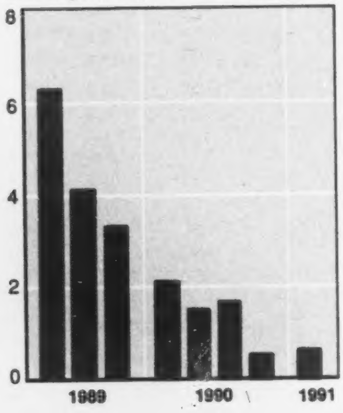
Profit margins

After-tax earnings as % of sales



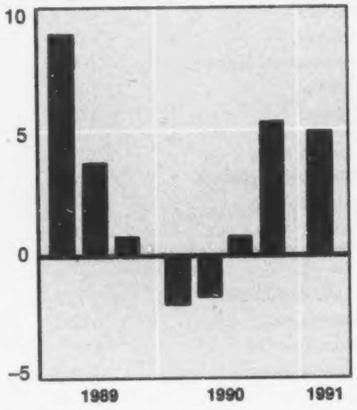
Production

% change from year-earlier quarter



Prices

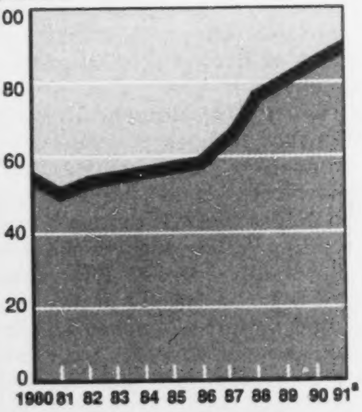
% change from year-earlier quarter



Sales in 1991 will rise about 4%, but earnings will be almost flat, lowering profit margins once again

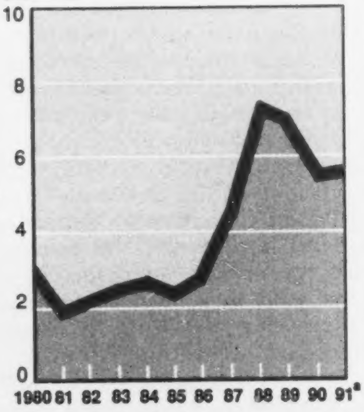
Annual sales

$ Billions



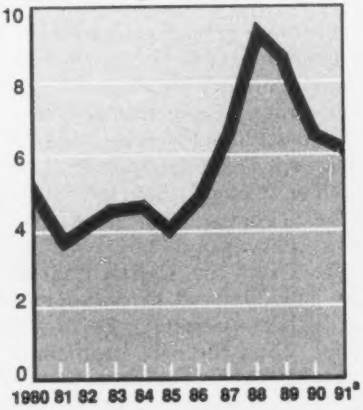
Annual earnings

$ Billions



Annual profit margins

After-tax earnings as % of sales



Note: All sales, earnings, and profit data are based on 30 chemical companies listed on page 12. a C&EN estimates.

Earnings for oil and drug firms up; diversified down

	FIRST-QUARTER 1991					
	Sales	Earnings[a]	Change from 1990		Profit margin[b]	
	($ millions)		Sales	Earnings	1991	1990
OIL AND GAS COMPANIES						
American Petrofina	$ 815.9	$ 8.3	−9%	−68%	1.0%	2.9%
Amoco	7,299.0	492.0	3	6	6.7	6.6
Ashland	2,036.2	26.6	−3	2810	1.3	0
Chevron	10,800.0	557.0	16	18	5.2	5.1
Exxon	30,685.0	2240.0	15	75	7.3	4.8
Kerr-McGee	785.6	29.7	0	10	3.8	3.4
Mobil	16,580.0	710.0	10	78	4.3	2.7
Occidental Petroleum	5,303.0	83.0	3	12	1.6	1.4
Phillips Petroleum	3,500.0	116.0	13	5	3.3	3.6
Shell Oil	5,668.0	125.0	−1	−38	2.2	3.5
Sun Co.	3,050.0	41.0	−2	0	1.3	1.3
Texaco	10,180.0	415.0	11	27	4.1	3.6
Unocal	2,717.0	53.0	3	−18	2.0	2.5
TOTAL	$99,419.7	$4896.6	9%	40%	4.9%	3.8%
DIVERSIFIED MANUFACTURERS						
Allied-Signal	$ 2903.0	$ 63.0	−5%	−51%	2.2%	4.2%
Du Pont	9,679.0	590.0	3	−4	6.1	6.5
Eastman Kodak	4,422.0	178.0	8	−11	4.0	4.8
Engelhard	628.7	21.1	−5	43	3.3	2.2
FMC	877.4	38.7	8	2	4.4	4.7
Ferro Corp.	262.9	2.9	−6	−52	1.1	2.1
3M	3,389.0	300.0	7	−10	8.9	10.6
NL Industries	225.0	−39.3	−1	def	def	10.8
PPG Industries	1,377.0	59.2	−7	−53	4.3	8.5
Tenneco	3,331.0	1.0	−8	−99	0	3.7
Vulcan Materials	197.0	−2.2	−15	def	def	8.0
TOTAL	$27,292.1	$1212.3	1%	−26%	4.4%	6.1%
PHARMACEUTICAL COMPANIES						
Abbott Laboratories	$ 1,653.6	$ 254.1	15%	13%	15.4%	15.6%
American Home Products	1,764.3	352.5	−3	12	20.0	17.3
Baxter International	2,122.0	110.0	12	def	5.2	def
Bristol-Myers Squibb	2,734.6	492.6	11	20	18.0	16.6
Merck	2,048.9	483.5	17	20	23.6	23.0
Pfizer	1,695.7	267.4	14	6	15.8	17.0
Schering-Plough	949.3	173.2	10	15	18.2	17.4
Upjohn	799.4	133.3	11	15	16.7	16.0
Warner Lambert	1,217.2	139.5	11	16	11.5	10.9
TOTAL	$14,985.1	$2406.1	11%	50%	16.1%	11.9%

a Earnings from operations excluding significant nonrecurring and extraordinary items. b Earnings as a percentage of sales. def = deficit.

12.1% from 13.6% in the first quarter last year.

Betz Laboratories reported earnings growth of 19% on a 14% increase in sales, and company chairman and chief executive John F. McCaughan stated, "We are especially pleased with our results, considering that they were achieved during a recessionary period. Both domestic and foreign operations contributed to our strong first-quarter performance."

Air Products & Chemicals, one of the chemical firms that does not fall into the smaller company category but which showed improvement, reported earnings growth of 14% on a 6% sales increase. And profitability rose to 8.2% from 7.6% in the first three months last year. Chairman Dexter F. Baker said, "Air Products' results were very good despite the increasing impact of the recession in the U.S. and evidence that economic activity has slowed throughout the world."

Not all companies were so fortunate, however. J. Lawrence Wilson, chairman of Rohm & Haas, where earnings dropped 24% on a 2% sales decrease, said: "The full impact of the U.S. recession and the European economic slowdown hit us full force in the middle of the quarter. Shipping volumes fell behind 1990 and continued at a lower pace through the end of the quarter. The plastics businesses particularly were hard hit in major markets. All businesses, except biocides and formulation chemicals, were hurt by external economic activity."

Dow Chemical, despite a 21% decline in earnings from operations, remained modestly optimistic. According to president and chief executive officer Frank Popoff, the global economy remains weak, although there is modest growth, primarily in the Pacific and continental Europe. "The weighted average growth of the 80 countries in which Dow does business should average between 0.5% and 1.0% in 1991, down from nearly 2% in 1990," Popoff said. And he sounded the hope of most of the industry: "The challenge of maintaining margins in an environment of soft economies and weak industry fundamentals typifies the current year. We anticipate modest improvement in 1992 versus 1991, based on the U.S. economy returning to positive growth by mid-1991."

Oil companies with large chemical operations followed the industry trend with mixed results. For instance, Exxon reported that earnings from its chemical operations climbed 23% to $223 million when compared with the year-earlier quarter. Mobil's chemical earnings rose 11% to $92 million in the first quarter. And Texaco had a 6% increase to $17 million.

Not all were so fortunate, however. Earnings at Shell, for instance, dropped 28% to $71 million.

Among the diversified firms, Du Pont, the largest U.S. chemical producer, saw earnings from its chemicals, polymers, and fibers operations fall almost 32% to $278 million. □

Costs creating ethylene feedstock problems

By the end of the year, cash cost economics will be setting ethylene prices. And this phenomenon will continue at least through 1993.

This means U.S. ethylene producers will face even greater pressure to minimize production costs. It also means that they will have to be more selective in choosing their feedstock.

That's the message that Thomas H. McGreevey brought to the recent meeting of the Chemical Management & Resources Association (CMRA) meeting in Philadelphia. McGreevey, director of CPI Consulting Associates, White Plains, N.Y., unloaded a few surprises at CMRA's review and forecast meeting.

For instance, light naphtha and gas oil will be more competitive than ethane as an ethylene feedstock, says McGreevey. In fact, he expects ethane to be the least competitive of all possible feedstocks.

For ethylene producers, oscillating feedstock economics is nothing new. They have been living with it for decades. Until the 1960s, the U.S. olefins industry was built on an abundant supply of natural gas liquid (NGL). Then, concerned about the future availability of NGL, some companies built ethylene crackers based on heavy liquids.

The crude oil crises of 1973 and 1979 forced producers to become more flexible. They revamped their heavy-liquids crackers to use a variety of feedstocks.

By the late 1980s, the U.S. petrochemical industry was operating at full capacity. By then, heavy liquids had become the feedstock of choice, says McGreevey.

Signs of weakness started to show up in petrochemical profits during the second half of 1989. They're still there, despite a temporary respite as a result of the Mideast crisis.

Meanwhile, higher crude prices during the second half of 1990 affected the competitive relationship between light and heavy feedstock, McGreevey says. But he thinks that an olefins producer's ability to switch from one feedstock to another as feedstock prices change will mean more competition—and a smaller price differential—among feedstocks.

Given this feedstock flexibility, price, more than availability, will be the key to feedstock choice in the 1990s, says McGreevey. That "nice generalization" is subject to several constraints, however. Heavy-liquids crackers, for instance, are flexible, but they cannot swing predominately to light liquids.

In addition, a company's ability to consume or market coproducts—and the value of those coproducts—can influence feedstock options. Constraints such as these can set the competitive relationship of feedstocks on its ear, as they did last year.

McGreevey sees three factors affecting an olefins producer's choice of feedstock over the next few years. They are domestic production of natural gas, reformulation of gasoline to meet Clean Air Act standards, and the price of crude oil and natural gas.

Forecasts of U.S. natural gas demand have ranged from virtually no growth to increases of as much as 2% per year. McGreevey leans toward the 2% growth scenario. He estimates that domestic natural gas output will increase from 18.9 trillion cu ft in 1990 to 20.9 trillion cu ft in 1995.

He concedes that his forecast may be optimistic because natural gas imports from Canada are expected to increase by 1995. Nevertheless, he says NGL availability should not be materially affected if domestic production comes in slightly lower. The reason is an anticipated increase in recovery efficiency.

Based on this forecast, McGreevey says that about 520,000 to 530,000 barrels per day of ethane probably will be available to the petrochemical industry. That's higher than 1989–90 levels, but consistent with that of prior years.

Over the past five years, refiners have increased propane availability 7% annually. Refineries now account for 45% of total supply. McGreevey says that, over the next five years, 510,000 to 520,000 bbl per day of propane will be available from gas-processing plants.

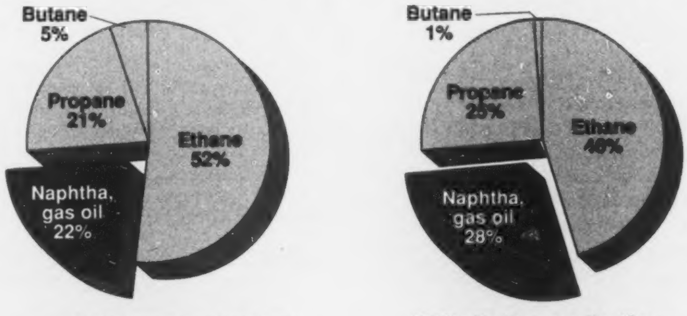
U.S. refineries and imports will have to supply the remaining 600,000 bbl per day. Although he says this appears reasonable, he believes an opportunity to improve profit margins probably will mean higher prices for petrochemical buyers.

n-Butane and isobutane are "probably the most interesting segment" of the NGL market, says McGreevey. He estimates that the gas-processing industry probably will produce 320,000 to 330,000 bbl per day of butanes in 1995, about 5% more than it is producing today.

In addition, refineries and imports have been adding about 150,000 to 200,000 bbl per day to U.S. supply recently. Now, with the Environmental Protection Agency mandating lower gasoline vapor pressure, butanes will be pulled out of gasoline. McGreevey estimates that, starting next year, an additional 150,000 bbl per day of *n*-butane will be available from the gasoline pool.

As a result, McCreevey estimates that the petrochemical industry could have available about 250,000

Ethylene producers will be using more heavy feedstock



1990 ethylene production = 37.6 billion lb

1995 ethylene production = 44.2 billion lb

Source: CPI Consulting Associates

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bbl per day of *n*-butane as feedstock in 1995. This assumes that refiners will continue to use all of their isobutane as alkylate and that Atlantic Richfield and Texaco will use 45,000 to 50,000 bbl per day for propylene oxide.

McGreevey also assumes that only 120,000 bbl per day of *n*-butane will be used for gasoline blending starting next year. And an additional 15,000 bbl per day will go into maleic anhydride and acetic acid.

Although there should be about 250,000 bbl per day of surplus *n*-butane available, McGreevey doesn't think that much of it will be used as feedstock for ethylene crackers. One reason is that not all of the *n*-butane backed out of the gasoline pool will be available on the Gulf Coast.

Another reason is the drive to build methyl *tert*-butyl ether (MTBE) capacity in the U.S. as refiners strive to meet ozone nonattainment regulations of the Clean Air Act. Although isomerization and dehydrogenation are the most expensive routes to isobutylene, *n*-butane appears to be the only alternative able to produce the 300,000 to 350,000 bbl per day of MTBE that will be needed to meet ozone and carbon monoxide nonattainment regulations.

As a result, the amount of light liquids available for ethylene in 1995 will account for slightly more than 70% of ethylene output. The remainder, says McGreevey, will come from naphtha and gas oil, with naphtha capturing about two thirds of the required feedstock.

His forecast assumes a moderate rise in crude oil prices (to $23 per bbl), reasonable economic growth, and ethylene output increasing at an annual growth rate of 3.3%.

The major unanswered question is: What kinds of feedstocks will be coming out of refineries as a result of the Clean Air Act? It is not yet clear how refiners will solve their need to meet future EPA requirements.

Will their oxygenate requirements be met solely by MTBE? Or will there be a combination of MTBE, ETBE (ethyl *tert*-butyl ether), ethanol, and methanol? The answers to these questions will help dictate ethylene's feedstock picture.

Earl Anderson

Number of New Chemistry Graduates Plunges Again

Last year was the seventh consecutive year of decline in B.S.-level graduates as fewer undergraduates opt for chemistry as a major

Michael Heylin, C&EN Washington

The nosedive in the number of new chemistry graduates earning bachelor's degrees continued last year. Even the number of new women chemists with bachelor's degrees is now in steady decline after a long period of growth. And it is apparent that native born American men today find chemistry far less attractive as an undergraduate major than they did even five years ago.

These are some of the major trends that can be gleaned from the data in the latest annual report of the American Chemical Society's Committee on Professional Training (CPT). The report (see page 32) lists the number of bachelor-, master-, and doctoral-level chemists who graduated during the 1989-90 academic year from departments with undergraduate chemistry programs approved by ACS. In recent years these departments have accounted for between 89 and 93% of all new B.S.-level chemists in the U.S. as well as for essentially all new M.S. and Ph.D. chemists.

At the advanced degree level, the picture is somewhat different. This is at least partly due to a much higher presence of foreign students. The number of new Ph.D. chemists increased last year for the 12th successive year. And the number of new M.S.-level chemists, although down last year, has held reasonably steady for the past decade.

One quarter of last year's new Ph.D. chemists were women. This was up from one fifth in 1984-85. Of the new M.S. graduates, 37% were women, up from 32% five years earlier.

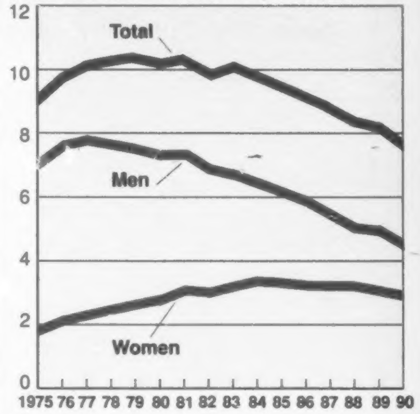
The 599 departments with CPT-approved programs graduated 7650 chemists with B.S. degrees in 1989-90. This was down from 8125 one year earlier. It represented a drop of 21% from the 9679 graduates five years earlier in 1984-85, and was the seventh consecutive year of decline.

The decline for male graduates earning B.S. chemistry degrees has been particularly sharp. Last year such graduates totaled 4614. This was down 26% from the 6263 who graduated in 1984-85 and represented a 42% decline from the high of 7903 in 1976-77.

Women have taken up some of the slack. In 1989-90 they represented 40% of the graduating B.S.-level chemists. This was up from 28% 10 years earlier and from 16% 20 years earlier. But in absolute terms, the number of women earning bachelor's chemistry degrees peaked in 1985 at 3416. It has been slipping since. Last year it was 3036, 11% below the 1985 level.

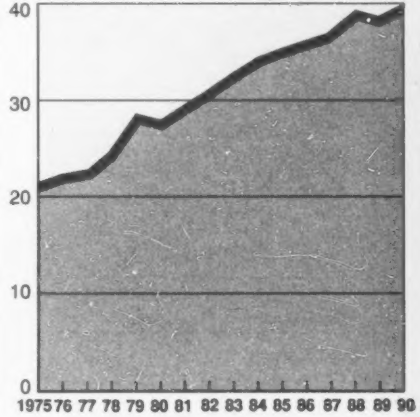
The decline in the number of B.S.-level chemistry graduates has affected most schools, even the largest and most prestigious. For many years, C&EN has identified from the CPT report and ranked the 25 largest producers of all bachelor's, ACS-certified bachelor's, master's, and doctoral degree chemistry graduates.

In 1984-85 the listing for B.S.-level chemistry graduates ranked the top 27 departments, since there was a four-way tie for the 24th place. All but one of these departments had smaller graduating classes in 1989-90. The exception was the University of Illinois, Urbana-Champaign, with 102 graduates in 1984-85 and 120 last year. The total for all 27 departments dropped 31% over this five-year period, from 1945 to 1343. Particularly big drops were posted



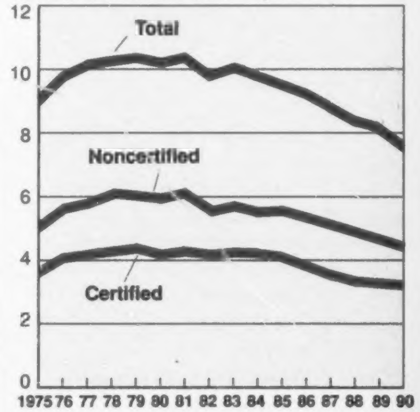
Men shy away from chemistry, women take up some slack . . .

Number of new B.S. chemists, thousands[a]



. . . and account for an increasing share of new graduates . . .

New women B.S. chemists as percent of total



. . . while gap between certified, noncertified degrees narrows

Number of new B.S. chemists, thousands[a]

[a] Number of B.S. chemistry degrees granted by departments with undergraduate chemistry programs approved by ACS's Committee on Professional Training.

by the University of Miami, from 99 to 21; the University of North Carolina, Chapel Hill, from 114 to 47; and Emory University, from 83 to 34.

Sixteen departments are common to the rankings of the top producers of bachelor's degree chemists for 1984–1985 and 1989–90. In 1984–85 these 16 graduated a total of 1240. Last year they graduated 1003, 19% fewer.

Last year was the sixth year in a row in which Indiana University produced the most B.S.-level chemistry graduates. The University of Illinois, Urbana-Champaign, hung onto second place, and the University of California, Los Angeles, moved up from fourth to third.

The biggest producer of ACS-certified B.S. graduates last year was the University of Texas, Austin, up from second in 1988–89. The second spot was shared by the University of Illinois, Urbana-Champaign, and Ohio State University. ACS-certified graduates, who in recent years have represented about 42% of all B.S.-level chemistry graduates, are immediately eligible for membership in ACS. They have completed a curriculum that meets guidelines specified by the society.

Last year was also the sixth year in a row in which the University of California, Berkeley, was the largest producer of doctoral chemists. Berkeley has topped this list for nine of the past 17 years. For the other eight years, the honor has gone to the University of Illinois, Urbana-Champaign, which was fifth last year. Massachusetts Institute of Technology graduated the second largest total of doctoral chemists last year, moving up from third in 1988–89. Purdue University made the reverse change, slipping from second to third.

Cornell University moved up from second to top the ranking for master's degree chemists. Northwestern University, leader in 1988–89, moved to second.

The University of Illinois, Urbana-Champaign; Indiana University; and Ohio State University had the only three departments to appear on last year's top 25 rankings for all categories—bachelor's, certified bachelor's, master's, and Ph.D. □

These schools had the most chemistry graduates, 1989–90

	Total bachelor graduates	
1.	Indiana U	132
2.	U of Illinois, Urbana-Champaign	120
3.	U of California, Los Angeles	83
4.	U of Texas, Austin	75
5.	U of Virginia	70
6.	U of Pittsburgh	68
7.	North Carolina State U	65
8.	U of California, Berkeley	59
9.	U of California, San Diego	57
10.	U of Maryland, College Park	55
11.	U of California, Irvine	51
12.	California State U, Long Beach	50
12.	U of Puerto Rico, Rio Piedras	50
14.	Miami U	49
14.	Youngstown State U	49
16.	U of Colorado, Boulder	48
17.	U of North Carolina, Chapel Hill	47
17.	U of South Florida	47
19.	U of Delaware	43
19.	Illinois State U	43
19.	Ohio State U	43
19.	U of Washington	43
23.	Case Western Reserve U	42
24.	Duke U	40
25.	U of Kansas	38
25.	West Virginia U	38

	Certified bachelor graduates	
1.	U of Texas, Austin	75
2.	U of Illinois, Urbana-Champaign	43
2.	Ohio State U	43
4.	Illinois State U	40
5.	U of California, San Diego	32
6.	Massachusetts Inst of Tech	31
6.	U of Minnesota, Minneapolis	31
8.	U of Delaware	30
8.	Harvard U	30
10.	U of Washington	29
11.	U of Cincinnati	28
11.	U of Michigan, Ann Arbor	28
13.	U of California, Davis	26
13.	Indiana U	26
13.	U of South Florida	26
13.	C of William & Mary	26
17.	North Carolina State U	25
18.	Carnegie Mellon U	22
18.	U of Wisconsin, Madison	22
20.	U of North Carolina, Chapel Hill	21
20.	Rensselaer Polytechnic Inst	21
20.	San Diego State U	21
23.	U of Akron	19
23.	California State U, Long Beach	19
25.	U of Chicago	18

	Master graduates	
1.	Cornell U	36
2.	Northwestern U	29
3.	Princeton U	28
4.	U of California, San Diego	25
5.	U of Rochester	24
6.	Ohio State U	23
7.	Yale U	21
8.	U of Washington	19
9.	U of Michigan, Ann Arbor	18
10.	Columbia U	17
10.	Illinois State U	17
12.	U of California, Los Angeles	16
12.	Indiana U	16
12.	San Jose State U	16
15.	Bowling Green State U	14
15.	U of Illinois, Urbana-Champaign	14
15.	U of Oklahoma	14
15.	Seton Hall U	14
19.	U of California, Berkeley	13
19.	Rensselaer Polytechnic Inst	13
19.	U of Cincinnati	13
19.	Harvard U	13
19.	Indiana/Purdue U, Indianapolis	13
24.	Johns Hopkins U	12
24.	Rutgers U, New Brunswick	12
24.	Washington U	12

	Doctoral graduates	
1.	U of California, Berkeley	67
2.	Massachusetts Inst of Tech	55
3.	Purdue U	50
4.	U of Wisconsin, Madison	47
5.	U of Illinois, Urbana-Champaign	44
6.	Texas A&M	42
7.	Iowa State U	34
7.	U of North Carolina, Chapel Hill	34
9.	U of California, Santa Barbara	32
9.	Indiana U	32
11.	U of California, Los Angeles	31
11.	Ohio State U	31
13.	Northwestern U	30
13.	Yale U	30
15.	Cornell U	29
15.	Harvard U	29
17.	Michigan State U	28
18.	U of Florida	27
19.	U of Colorado, Boulder	26
19.	U of Michigan, Ann Arbor	26
21.	U of Chicago	25
22.	Colorado State U	24
22.	U of Maryland, College Park	24
22.	U of Minnesota, Minneapolis	24
22.	U of South Carolina	24

ACS Committee on Professional Training 1990 Annual Report

Summary of data from departments offering an ACS-approved program, 1986–90

	Bachelors				Masters		Doctorates	
	Number of schools	Graduates (totals)	Certified graduates[a]	Noncertified graduates	Number of schools	Graduates	Number of schools	Graduates
CHEMISTRY								
1986	580	9295	3892	5403	315	1620	187	1885
1987	582	8848	3663	5185	316	1636	188	1936
1988	584	8372	3453	4919	319	1584	192	1955
1989	593	8125	3384	4741	318	1710	189	1970
1990	599	7650	3213	4437	317	1605	187	2131
CHEMICAL ENGINEERING[b]								
1986	118	5229	5229	—	116	1244	103	460
1987	107	4435	4435	—	103	1078	90	533
1988	128	3524	3524	—	124	1036	106	603
1989	115	2891	2981	—	113	919	95	574
1990	126	3170	3170	—	122	956	106	583

a Includes graduates certified in approved options. b Chemical engineering departments are not required to report their data to CPT, so the number of departments included in this category varies from year to year.

The number of bachelor's degree graduates in chemistry from colleges and universities whose undergraduate chemistry programs are approved by the American Chemical Society decreased 5.8% in the 1989–90 academic year. This almost doubled the loss of last year. The number of master's degrees from these departments dropped 6.1% after an increase of 7.5% last year. The number of Ph.D. degrees continued to increase for the 12th year in a row; the increase was 8.2%.

The percentage of baccalaureate graduates certified to ACS was 42%, about the same as previous years. (Certified graduates are those who have completed a curriculum that meets the guidelines specified by ACS and are eligible for full membership in ACS; noncertified graduates may become associate members of ACS upon graduation and full members after three years of professional experience or after obtaining a higher degree in a chemical science.)

A total of 2151 of the baccalaureate graduates from the approved schools were reported as planning to go to graduate school, and 1567 reported plans to go to professional schools.

Total numbers of bachelor's degrees (certified and noncertified), master's degrees, and Ph.D. degrees awarded in 1989–90 by departments whose undergraduate chemistry programs are ACS approved are listed by institution in the large table at the end of this report and are summarized in the two smaller tables. These tables also include numbers of chemical engineering graduates from institutions whose programs are accredited by the American Institute of Chemical Engineers and the Accreditation Board for Engineering & Technology. (Note: These departments are not required to report their data to the Committee on Professional Training, so the number of departments included varies each year.) Included for the sixth year is a table with information on graduate student enrollments in chemistry departments whose undergraduate programs are ACS approved.

The number of bachelor's degrees in chemical engineering from the 126 AIChE-ABET-accredited departments that reported in 1990 increased 9.6% from the total reported by 115 departments in 1989, the first increase in seven years. At the graduate level, the number of chemical engineering master's degrees increased for the first time in five years and Ph.D. degrees showed a slight increase over last year. The number of master's degrees was up 4% from 1989, and the number of Ph.D.s was up 1.5%.

The chemistry programs at ACS-approved schools normally are reevaluated at five-year intervals. There were 599 colleges and universities on the approved list at the end of 1990. During the year the committee studied the reports of 303 chemistry programs at approved schools and 20 reports from schools applying for ACS approval. Each evaluation involved a review of extensive documentary materials submitted by the

Summary of totals from 1990 reports from departments offering an ACS-approved program

	Schools reporting	Men	Women	Total
CHEMISTRY				
Bachelors, Total	599	4614	3036	7650
Certified		1986	1227	3213
Noncertified		2628	1809	4437
Masters	317	1007	598	1605
Doctorates	187	1607	524	2131
CHEMICAL ENGINEERING				
Bachelors,				
Certified	126	2217	953	3170
Masters	122	784	172	956
Doctorates	106	508	75	583

department chairman describing the current status of the program.

Six schools were added to the ACS-approved list by CPT in 1990; three were put on probation; seven were removed from probation; four continued on probation; and none was removed from the list. Visiting associates of the committee made on-site visits to nine schools.

In 1990 the committee added two more options to the list of certified degrees. Currently students may receive certified degrees in chemistry with options in biochemistry, polymers, chemistry education, chemical physics, or materials. By the end of 1990, the committee had approved 23 programs with a biochemistry option; three with a polymers option; and one chemistry education option.

CPT presented a symposium on "Innovative Approaches to the Teaching of Introductory Chemistry" in cooperation with the ACS Division of Chemical Education and the National Science Foundation at the fall 1990 ACS national meeting. The symposium focused on the critical need for curricular revision of the general chemistry programs at U.S. colleges and universities and examined the feasibility and vitality of nontraditional approaches to teaching introductory chemistry. Proceedings of the symposium will be available this spring and will be distributed to all ACS-approved schools. Copies may be requested from: Office of Professional Training, American Chemical Society, 1155—16th St., N.W., Washington, D.C. 20036.

As an added service to the users of the "ACS Directory of Graduate Research," the committee approved an on-line version of the directory on ACS/ECOM. All data elements in the DGR, except publications, are searchable in the on-line system. Information on accessing this database may be obtained from Cathi Buzalski, ACS/ECOM System Administrator, 1155—16th St., N.W., Washington, D.C. 20036, (800) 227-5558 or (202) 872-6016.

Also, as an aid to undergraduate students studying chemistry, the committee published a revised fifth edition of the booklet titled Planning for Graduate Work in Chemistry. This helpful publication addresses the reasons for going to graduate school, the admission process, choice of graduate school, how and when to apply, availability of financial support, and preparation for graduate school. Copies of Planning for Graduate Work in Chemistry are available from the Office of Professional Training, American Chemical Society, 1155—16th Street, N.W., Washington, D.C. 20036.

Other CPT activities in 1990 included approval of a "Research Reports" appendix to the guidelines for ACS-approved schools; publication of issue number six of the *CPT Newsletter*; inauguration of a plan to revise existing appendixes to the "ACS Guidelines & Evaluation Procedures"; discussion of a proposal for changes in CPT data compilation and analysis; and continuation of development of a subject index in the "ACS Directory of Graduate Research."

CPT wishes to acknowledge and thank the following visiting associates of the committee who conducted on-site visits to schools on the approved list or applying for ACS approval during 1990: Charles A. Arrington Jr., Furman University; Slayton A. Evans, University of North Carolina, Chapel Hill; Quintus Fernando, University of Arizona; Dennis J. Fife, Thiokol Corp.; Donald E. Jones, Western Maryland College; J. Ivan Legg, Auburn University; John P. Lowe, Pennsylvania State University; Robert W. Parry, University of Utah; Herman G. Richey, Pennsylvania State University; and Charles A. Root, Bucknell University. □

Committee members, 1990

Marjorie C. Caserio,
committee chairman
University of California, San Diego
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Cornell University
Norman C. Craig
Oberlin College
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Trinity University
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committee secretary
Cathy A. Nelson, *staff associate*
Dolphine S. Hite, *program assistant*
American Chemical Society

Graduate student enrollments in departments whose undergraduate chemistry programs are ACS approved

	Number of departments	First-year graduate students		All graduate students	
		Full-time	Part-time	Full-time	Part-time
M.S. DEPARTMENTS[a]					
Fall 1985	129	417	292	1,106	962
Fall 1986	128	474	264	1,190	1051
Fall 1987	127	406	315	1,136	993
Fall 1988	127	420	218	998	855
Fall 1989	131	429	238	1,013	834
Ph.D. DEPARTMENTS					
Fall 1985	187	3455	208	14,379	1372
Fall 1986	187	3475	235	14,438	1355
Fall 1987	192	3441	201	15,212	1231
Fall 1988	189	3320	171	15,125	1111
Fall 1989	187	3464	159	15,222	1207

[a] Departments whose highest offering is the master's degree in chemistry.

Chemistry and chemical engineering degrees awarded by schools offering an ACS-approved program, 1989–90

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelors certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Abilene Christian U	7	3	1	0			
Adelphi U	0	2	4	—			
Agnes Scott C	1	0	—	—			
Akron, U of	19	7	5	5	a		
Alabama, U of							
Birmingham	2	3	2	6			
Huntsville	1	4	6	—	a		
Tuscaloosa	1	12	1	8	19	9	0
Alaska Fairbanks, U of	2	7	2	—			
Albion C	1	14	—	—			
Albright C	5	9	—	—			
Alfred U	3	0	—	—			
Allegheny C	0	11	—	—			
Alma C	3	3	—	—			
American U	2	0	4	2			
Amherst C	1	9	—	—			
Andrews U	2	1	—	—			
Appalachian State U	4	11	0	—			
Arizona State U	15	10	3	13	25	4	5
Arizona, U of	12	10	4	13	13	3	1
Arkansas State U	0	7	0	—			
Arkansas Tech U	3	2	—	—			
Arkansas, U of							
Fayetteville	4	6	4	9	33	10	2
Little Rock	3	7	2	—			
Ashland U	0	3	—	—			
Auburn U	2	9	6	3	21	21	4
Augsburg C	2	1	—	—			
Augustana C							
Illinois	0	9	—	—			
South Dakota	2	2	—	—			
Austin C	0	6	—	—			
Baldwin-Wallace C	2	9	—	—			
Ball State U	4	3	2	—			
Barnard C	0	18	—	—			
Bates C	2	6	—	—			
Baylor U	7	29	1	0			
Beloit C	2	13	—	—			
Bemidji State U	3	13	—	—			
Birmingham-Southern C	3	1	—	—			
Bloomsburg U	5	4	—	—			
Boston C	6	0	3	5			
Boston U	9	10	5	5			
Bowdoin C	1	27	—	—			
Bowling Green State U	7	9	14				
Bradley U	3	3	0	—			
Brandeis U	0	1	6	8			
Bridgeport, U of	0	0	3	—			
Bridgewater State C	2	4	1	—			
Brigham Young U	16	13	5	4	26	8	5
Brown U	0	14	1	14	1	0	1
Bryn Mawr C	11	0	6	1			
Bucknell U	14	18	2	—	21	4	—
Butler U	3	9	1	—			
California Institute of Tech	6	0	2	21	5	4	14
California Poly State U	7	28	2	—			
California State Poly U	8	10	5	—	a		
California State U							
Bakersfield	1	4	—	—			
Chico	0	6	—	—			
Dominguez Hills	2	4	—	—			
Fresno	7	5	5	—			
Fullerton	4	21	4	—			
Hayward	13	12	5	—			
Long Beach	19	31	10	—	a		
Los Angeles	2	13	4	—			
Northridge	7	21	10	—			
Sacramento	9	8	6	—			
San Bernardino	2	5	—	—			
Stanislaus	5	9	—	—			
California, U of							
Berkeley	11	48	13	67	71	13	15
Davis	26	7	4	14	28	5	3
Irvine	13	38	10	22			
Los Angeles	11	72	16	31	15	5	8
Riverside	12	0	3	11			
San Diego	32	25	25	19	17	8	1
Santa Barbara	15	0	8	32	21	7	7
Santa Cruz	6	12	3	9			

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelors certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Calvin C	5	11	—	—			
Canisius C	5	5	—	—			
Capital U	2	2	—	—			
Carleton C	8	11	—	—			
Carnegie Mellon U	22	3	7	6	29	11	12
Carroll C	4	9	—	—			
Carthage C	1	1	—	—			
Case Western Reserve U	5	37	6	19	25	5	4
Catholic U of America	0	2	3	3			
Centenary C of Louisiana	1	2	—	—			
Central C	0	9	—	—			
Central Connecticut State U	4	2	0				
Central Florida, U of	15	0	4	—			
Central Michigan U	0	18	3	—			
Central State U							
Ohio	0	2	—	—			
Oklahoma	5	13	—	—			
Centre C	2	5	—	—			
Charleston, C of	4	10	—	—			
Chatham C	3	0	—	—			
Chestnut Hill C	3	2	—	—			
Chicago State U	0	4	—	—			
Chicago, U of	18	12	11	25			
Christian Brothers C[b]					a		
Cincinnati, U of	28	0	13	19	47	5	4
Citadel, The	0	4	—	—			
City U of New York							
Graduate Center	—	—	—	7			
Brooklyn C	0	17	10	—			
City C	2	15	11	—	11	13	3
Herbert H. Lehman C	[illegible]	10	—	—			
Hunter C	[illegible]	[illegible]	—	—			
Queens C	0	14	4	—			
Clarion U	3	1	—	—			
Clark U	3	2	2	2			
Clarkson U	6	2	5	10	38	19	4
Clemson U	6	0	4	5	40	6	2
Cleveland State U	13	0	8	8	14	4	4
Coe C	0	2	—	—			
Colby C	2	8	—	—			
Colgate U	10	4	—	—			
Colorado C	8	4	—	—			
Colorado School of Mines	5	0	6	5	52	14	1
Colorado State U	10	5	1	24	20	7	0
Colorado, U of							
Boulder	12	36	8	26	31	8	3
Colorado Springs	4	2	—	—			
Denver	4	3	1	—			
Columbia U	4	4	17	20	18	15	5
Concordia C	1	4	—	—			
Connecticut C	3	7	—	—			
Connecticut, U of	13	7	6	10	20	13	3
Cooper Union[b]					a		
Cornell C	0	4	—	—			
Cornell U	16	15	36	29	31	4	7
Creighton U	15	6	0	—			
Dartmouth C	0	13	2	6			
David Lipscomb U	1	14	—	—			
Davidson C	5	5	—	—			
Dayton, U of	5	3	—	—	25	3	—
De Paul U	2	8	7	—			
DePauw U	4	9	—	—			
Delaware State C	1	5	2	—			
Delaware Valley C of Science & Agriculture	3	0	—	—			
Delaware, U of	30	13	3	15	33	5	16
Delta State U	2	7	—	—			
Denison U	3	2	—	—			
Denver, U of	0	6	2	2			
Detroit Mercy, U of	1	3	7	3	a		
Dickinson C	1	17	—	—			
District of Columbia, U of the	3	2	—	—			
Drake U	3	3	—	—			
Drew U	2	5	—	—			
Drexel U	5	2	8	4	38	7	1
Duke U	11	29	3	19			
Duquesne U	0	7	1	0			
Earlham C	0	8	—	—			
East Carolina U	6	3	4	—			

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelors certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
East Stroudsburg U	2	9	0	—			
East Tennessee State U	4	4	3	—			
East Texas State U	0	1	3	—			
Eastern Illinois U	9	6	3	—			
Eastern Kentucky U	0	13	3	—			
Eastern Michigan U	6	10	6	—			
Eastern New Mexico U	3	1	0	—			
Eckerd C	2	1	—	—			
Elizabethtown C	1	7	—	—			
Elmhurst C	2	6	—	—			
Emory U	3	31	4	17			
Emporia State U	3	1	5	—			
Evansville, U of	2	1	—	—			
Fairfield U	3	0	—	—			
Fairleigh Dickinson U							
Madison	3	0	4	—			
Teaneck	7	0	0	—			
Fisk U	3	0	3	—			
Florida A&M U	0	2	—	—			
Florida Atlantic U	5	14	4	—			
Florida Institute of Tech	1	3	0	0	6	5	—
Florida International U	4	7	0	—			
Florida State U	3	21	5	11	a		
Florida, U of	5	27	6	27	36	6	7
Fordham U	2	4	1	—			
Fort Lewis C	1	12	—	—			
Framingham State C	2	1	—	—			
Franklin & Marshall C	10	4	—	—			
Furman U	14	10	0	—			
Geneva C	2	11	—	—			
George Mason U	8	0	1	—			
George Washington U	2	7	0	2			
Georgetown U	11	0	5	7			
Georgia Institute of Tech	17	0	9	6	55	8	8
Georgia Southern U	2	0	—	—			
Georgia State U	0	5	0	—			
Georgia, U of	8	7	4	7			
Gettysburg C	4	1	—	—			
Glassboro State C	5	1	—	—			
Gonzaga U	2	0	—	—			
Goucher C	0	4	—	—			
Grand Valley State U	1	14	—	—			
Grinnell C	5	10	—	—			
Gustavus Adolphus C	1	7	—	—			
Hamilton C	1	2	—	—			
Hamline U	3	4	—	—			
Hampden-Sydney C	2	2	—	—			
Hampton U	9	0	3	—			
Hartford, U of	3	0	0	—			
Hartwick C	2	1	—	—			
Harvard U	30	0	13	29			
Harvey Mudd C	12	0	—	—			
Haverford C	15	1	—	—			
Hawaii, U of	10	7	5	2			
Hendrix C	4	8	—	—			
Hiram C	3	3	—	—			
Hobart & William Smith C	0	7	—	—			
Hofstra U	2	3	—	—			
Hollins C	0	3	—	—			
Holy Cross, C of the	15	3	—	—			
Hope C	14	9	—	—			
Houston, U of	5	1	5	13	17	7	9
Howard U	1	21	1	1	5	4	—
Humboldt State U	3	2	—	—			
Idaho State U	6	4	0	—			
Idaho, U of	6	8	6	3	12	8	1
Illinois Benedictine C	13	0	—	—			
Illinois Institute of Tech	4	0	1	0	25	5	12
Illinois State U	40	3	17	—			
Illinois Wesleyan U	4	1	—	—			
Illinois, U of							
Chicago	8	22	10	15	20	7	1
Urbana-Champaign	43	77	14	44	56	9	12
Indiana State U	7	0	3	—			
Indiana U	26	106	16	32			
Indiana U Northwest	2	0	—	—			
Indiana U, South Bend	3	0	—	—			
Indiana U of Pennsylvania	12	4	3	—			
Indiana U-Purdue U							
Fort Wayne	1	6	—	—			
Indianapolis	1	12	13	—			
Interamerican U of Puerto Rico	2	5	—	—			
Iowa State U	8	4	4	34	46	14	6
Iowa, U of	16	2	4	8	14	1	3
Ithaca C	6	2	—	—			
Jackson State U	4	5	2	—			
James Madison U	8	8	—	—			
John Carroll C	5	14	5	—			
Johns Hopkins U	11	0	12	5	16	4	0
Juniata C	4	12	—	—			
Kalamazoo C	6	6	—	—			
Kansas State U	1	1	3	6	21	3	2
Kansas, U of	12	26	3	8	20	7	4
Kean C of New Jersey	4	13	—	—			
Kearney State C	1	18	—	—			
Kennesaw C	2	0	—	—			
Kent State U	16	4	2	4			
Kentucky, U of	7	12	3	7	20	6	1
Kenyon C	3	7	—	—			
King's C	4	1	—	—			
Knox C	0	16	—	—			
La Salle U	5	1	—	—			
Lafayette C	6	4	—	—	14	—	—
Lake Forest C	1	7	—	—			
Lamar U	5	0	4	—	32	8	0
Lawrence Technological U	14	0	—	—			
Lawrence U	3	3	—	—			
Le Moyne C	4	0	—	—			
Lebanon Valley C	1	5	—	—			
Lehigh U	3	3	5	15	25	12	12
Lewis & Clark C	1	0	—	—			
Lincoln U	0	6	—	—			
Long Island U							
Brooklyn Center	1	2	7	—			
C. W. Post Center	1	2	—	—			
Loras C	4	0	—	—			
Louisiana State U							
Baton Rouge	5	8	4	13	18	6	3
Shreveport	5	0	—	—			
Louisiana Technological U	1	4	0	—	12	3	—
Louisville, U of	5	15	2	8	—	18	3
Lowell, U of	4	5	6	13	20	3	—
Loyola C in Maryland	3	3	—	—			
Loyola Marymount U	4	0	—	—			
Loyola U							
Chicago	8	10	0	5			
New Orleans	0	4	—	—			
Luther C	0	8	—	—			
Macalester C	3	5	—	—			
Maine, U of	4	1	2	5	22	5	1
Manhattan C[c]	5	0	—	—	12	15	—
Manhattanville C	1	0	—	—			
Mankato State U	7	10	1	—			
Marietta C	2	1	—	—			
Marist C	1	1	—	—			
Marquette U	7	0	3	6			
Marshall U	3	14	0	—			
Maryland, U of							
Baltimore County	9	16	6	4	a		
College Park	16	39	10	24	33	1	5
Massachusetts Institute of Tech	31	0	2	55	32	38	42
Massachusetts, U of	7	3	8	13	22	4	11
McNeese State U	1	0	2	—			
Memphis State U	2	14	2	3			
Mercer U	0	2	—	—			
Merrimack C	7	0	—	—			
Metropolitan State C	3	18	—	—			
Miami U	16	33	6	6			
Miami, U of	2	19	3	2			
Michigan State U	15	17	11	28	39	8	3
Michigan Technological U	12	0	1	1	43	3	—
Michigan, U of							
Ann Arbor	28	0	18	26	54	10	9
Dearborn	9	13	—	—			
Flint	4	1	—	—			
Middle Tennessee State U	0	9	3	—			
Middlebury C	2	16	—	—			
Midwestern State U	1	8	—	—			
Millersville U	5	8	—	—			
Millsaps C	1	10	—	—			
Minnesota, U of							
Duluth	4	8	6	—			
Minneapolis	31	0	10	24	76	8	29
Mississippi C	4	9	—	—			
Mississippi State U	1	7	5	7	a		

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelors certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Mississippi, U of	0	3	1	3	6	7	0
Missouri Western State C	7	2	—	—			
Missouri, U of							
Columbia	15	0	7	8	25	4	4
Kansas City	3	11	0	0			
Rolla	5	0	5	10	41	10	1
St. Louis	7	4	7	3			
Monmouth C	0	1	—	—			
Montana C of Mineral Science & Technology	2	4	4	—			
Montana State U	2	4	4	22	31	1	0
Montana, U of	3	3	3	3			
Montclair State C	3	8	1	—			
Moorhead State U	4	2	—	—			
Moravian C	2	6	—	—			
Morehouse C	4	1	—	—			
Morgan State U	3	3	—	—			
Mount Holyoke C	4	10	1	—			
Mount Saint Vincent, C of[c]	0	1	—	—			
Muhlenberg C	0	14	—	—			
Murray State U	2	10	4	—			
Muskingum C	0	8	—	—			
Nebraska, U of							
Lincoln	5	7	7	8	10	4	2
Omaha	7	1	—	—			
Nebraska Wesleyan U	2	2	—	—			
Nevada, U of							
Las Vegas	0	5	1	—			
Reno	2	3	1	2	[illegible]	—	—
New Hampshire, U of	10	2	8	11	[illegible]	5	0
New Jersey Institute of Tech[b]					[illegible]	11	1
New Mexico Highlands U	0	0	0	—			
New Mexico Institute of Mining & Tech	6	0	3	2			
New Mexico State U	3	11	7	4	7	2	1
New Mexico, U of	3	8	4	7	9	4	2
New Orleans, U of	2	8	2	5			
New York U	0	31	5	14			
Niagara U	0	2	—	—			
North Alabama, U of	0	9	—	—			
North Carolina A&T State U	4	0	0	—			
North Carolina Central U	1	2	2	—			
North Carolina State U	25	40	5	7	69	4	7
North Carolina, U of							
Asheville	3	2	—	—			
Chapel Hill[e]	21	26	11	34			
Charlotte	8	5	3	—			
Greensboro	5	3	2	—			
Wilmington	5	11	0	—			
North Dakota State U	0	15	3	7			
North Dakota, U of	2	4	4	3	15	3	—
North Texas, U of	6	3	11	6			
Northeast Louisiana U	1	0	5	—			
Northeast Missouri State U	3	3	—	—			
Northeastern Illinois U	1	10	6	—			
Northeastern U	4	0	2	9	a		
Northern Arizona U	5	21	1	—			
Northern Colorado, U of	1	7	0	0			
Northern Illinois U	9	14	10	5			
Northern Iowa, U of	2	13	1	—			
Northern Kentucky U	3	4	—	—			
Northern Michigan U	2	3	0	—			
Northwest Missouri State U	1	0	—	—			
Northwestern State U	0	0	—	—			
Northwestern U	11	13	29	30	15	10	11
Notre Dame, U of	3	10	2	10	26	11	5
Oakland U	6	0	1	—			
Oberlin C	3	14	—	—			
Occidental C	13	7	—	—			
Ohio Northern U	3	3	—	—			
Ohio State U	43	0	23	31	38	18	4
Ohio U	3	15	2	1	16	5	0
Ohio Wesleyan U	2	2	—	—			
Oklahoma State U	3	1	7	11	10	6	4
Oklahoma, U of	10	13	14	9	14	8	6
Old Dominion U	5	6	7	—			
Oregon State U	9	0	0	13	a		
Oregon, U of	4	24	5	16			
Pace U							
New York	0	4	—	—			
Pleasantville	1	3	—	—			
Pacific Lutheran U	3	9	—	—			
Pacific, U of the	1	7	4	1			
Pennsylvania State U	10	11	1	23	95	12	3
Pennsylvania, U of	3	14	3	18	14	11	13
Philadelphia C of Pharmacy & Science	2	2	1	0			
Philadelphia C of Textiles & Science	3	0	—	—			
Pittsburg State U	0	2	1	—			
Pittsburgh, U of	14	54	6	17	25	14	10
Polytechnic U	0	1	11	19	4	11	4
Pomona C	2	6	—	—			
Portland State U	0	10	1	3			
Portland, U of	3	0	—	—			
Pratt Institute[b]					3	—	—
Princeton U	10	8	28	17	12	2	9
Providence C	3	1	0	0			
Puerto Rico, U of							
Mayaguez	4	13	5	—	66	11	—
Rio Piedras	17	33	5	6			
Puget Sound, U of	7	0	—	—			
Purdue U	14	14	11	50	92	7	17
Purdue U Calumet	0	5	—	—			
Ramapo C of New Jersey	1	0	—	—			
Randolph-Macon C	0	2	—	—			
Randolph-Macon Woman's C	1	6	—	—			
Redlands, U of	1	2	—	—			
Reed C	7	6	—	—			
Rensselaer Polytechnic Inst	21	0	13	9	35	5	6
Rhode Island C	5	1	—	—			
Rhode Island, U of	3	1	4	4	11	3	3
Rhodes C	4	3	—	—			
Rice U	3	1	11	16	10	3	9
Richmond, U of	0	11	—	—			
Rider C	1	0	—	—			
Ripon C	6	1	—	—			
Roanoke C	3	1	—	—			
Rochester Institute of Tech	5	18	7	—			
Rochester, U of	5	2	24	18	17	13	4
Rockhurst C	2	6	—	—			
Rollins C	0	6	—	—			
Roosevelt U	4	2	10	—			
Rose-Hulman Institute of Tech	9	0	—	—	34	0	—
Russell Sage C	1	0	—	—			
Rutgers U							
Camden C	3	4	—	—			
New Brunswick	9	26	12	19	31	12	10
Newark C of Arts & Sciences	4	6	7	3			
Saginaw Valley State U	3	10	—	—			
St. Anselm C	1	1	—	—			
St. Catherine, C of	5	4	—	—			
St. Cloud State U	4	12	—	—			
St. John Fisher C	3	0	—	—			
St. John's U/C of St. Benedict	4	11	—	—			
St. John's U	6	0	1	—			
St. Joseph C	0	2	3	—			
St. Joseph's U	15	6	4	—			
St. Lawrence U	2	7	—	—			
St. Louis U	11	24	6	—			
St. Mary's C	1	6	—	—			
St. Michael's C	1	1	—	—			
St. Olaf C	2	33	—	—			
St. Peter's C	1	1	—	—			
St. Thomas, U of	0	8	—	—			
St. Vincent C[d]	3	1	—	—			
Salem State C	0	0	—	—			
Sam Houston State U	7	4	4	—			
San Diego State U	21	5	8	2			
San Francisco State U	9	20	8	—			
San Francisco, U of	3	2	4	—			
San Jose State U	15	8	16	—	a		
Sangamon State U	2	0	—	—			
Santa Clara U	0	4	—	—			
Scranton, U of	3	10	9	—			
Seattle U	1	5	—	—			
Seton Hall U	5	7	14	5			
Seton Hill C[d]	0	0	—	—			
Shippensburg U	3	2	1	—			
Siena C	6	0	—	—			
Simmons C	0	3	—	—			
Skidmore C	0	10	—	—			
Smith C	3	4	—	—			
Sonoma State U	2	5	—	—			
South Alabama, U of[b]					13	0	—
South Carolina, U of	6	26	4	24	19	5	1

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelors certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
South Dakota School of Mines & Tech	6	1	2	—	18	1	—
South Dakota State U	1	14	4	0			
South Dakota, U of	0	5	2	—			
South Florida, U of	26	21	6	9	8	11	0
Southeast Missouri State U	3	8	—	—			
Southeastern Louisiana U	1	0	—	—			
Southeastern Massachusetts U	4	2	0	—			
Southern California, U of	12	4	6	16	15	4	2
Southern Colorado U	2	5	1	—			
Southern Illinois U							
Carbondale	4	4	4	3			
Edwardsville	2	2	8	—			
Southern Methodist U	3	7	0	—			
Southern Mississippi, U of	1	15	0	1			
Southern Oregon State C	2	5	—	—			
Southern U and A&M C	1	1	6	—			
Southwest Missouri State U	6	17	—	—			
Southwest State U	2	6	—	—			
Southwest Texas State U	11	0	5	—			
Southwestern Louisiana, U of	1	4	0	—	a		
Southwestern Oklahoma State U	3	5	—	—			
Stanford U	10	2	3	17	9	31	10
State U of New York							
Albany	7	3	4	9			
Binghamton	6	11	5	3			
Buffalo	13	10	8	14	28	8	7
Stony Brook	17	18	8	12			
C at Brockport	1	3	—	—			
C at Buffalo	2	7	2	—			
C at Cortland	1	4	—	—			
C at Fredonia	2	6	2	—			
C at Geneseo	3	4	—	—			
C at New Paltz	3	5	1	—			
C at Oneonta	0	8	0	—			
C at Oswego	12	2	2	—			
C at Plattsburgh	7	9	1	—			
C at Potsdam	0	9	—	—			
C at Purchase	2	4	—	—			
Stephen F. Austin State U	9	0	2	—			
Stetson U	1	2	—	—			
Stevens Institute of Tech	2	5	10	4	9	11	5
Stockton State C	1	8	—	—			
Suffolk U	2	3	—	—			
Susquehanna U	0	6	—	—			
Swarthmore C	8	4	—	—			
Syracuse U	8	3	3	10	7	2	6
Temple U	15	3	6	4			
Tennessee Technological U	4	4	2	—	11	6	0
Tennessee, U of							
Chattanooga	8	14	—	—			
Knoxville	5	13	8	15	32	13	3
Martin	5	4	—	—			
Texas A&I U	3	0	2	—	a		
Texas A&M U	8	13	7	42	58	13	6
Texas Christian U	1	9	1	3			
Texas Southern U	6	0	3	—			
Texas Tech U	9	12	3	9	a		
Texas, U of							
Arlington	9	6	6	5			
Austin	75	0	9	22	83	19	18
Dallas	5	0	2	4			
El Paso	12	0	9	—			
Texas Woman's U	1	2	2	—			
Thiel C	2	2	—	—			
Thomas More C	1	1	—	—			
Toledo, U of	7	7	6	4	10	11	2
Towson State U	2	2	—	—			
Trenton State C	16	0	—	—			
Tri-State U[b]					5	—	—
Trinity C	6	8	0	—			
Trinity U	3	7	—	—			
Tufts U	0	13	9	5	12	7	2
Tulane U of Louisiana	0	15	2	6	a		
Tulsa, U of	5	1	—	—	25	7	1
Tuskegee Institute	0	7	1	—	11	—	—
Union C	3	6	—	—			
U.S. Air Force Academy	12	0	—	—			
U.S. Naval Academy	14	0	—	—			
Ursinus C	5	6	—	—			
Utah State U	12	0	6	8			
Utah, U of	7	18	5	23	16	5	3
Valparaiso U	4	19	—	—			
Vanderbilt U	1	14	7	4	13	4	1
Vassar C	2	4	3	—			
Vermont, U of	8	0	1	5			
Villanova U	4	0	9	1	19	4	—
Virginia Commonwealth U	8	19	3	9			
Virginia Military Institute	6	0	—	—			
Virginia Polytechnic Institute & State U	17	8	10	19	30	2	4
Virginia, U of	6	64	5	7	29	27	8
Wabash C	6	4	—	—			
Wagner C	1	0	—	—			
Wake Forest U	16	0	4	1			
Washburn U	0	5	—	—			
Washington C	3	0	—	—			
Washington State U	4	4	9	9	13	13	0
Washington U	8	9	12	9	15	15	7
Washington, U of	29	14	19	20	51	11	10
Washington & Jefferson C	4	24	—	—			
Washington & Lee U	1	14	—	—			
Wayne State U	10	16	6	12	20	12	5
Waynesburg C	2	1	—	—			
Weber State C	4	2	—	—			
Wellesley C	4	17	—	—			
Wesleyan U	1	4	1	5			
West Chester U	6	17	2	—			
West Florida, U of	8	2	—	—			
West Texas State U	1	3	0	—			
West Virginia Institute of Tech[b]					5	2	—
West Virginia State C	4	3	—	—			
West Virginia U	5	33	3	3	18	4	2
Western Illinois U	2	5	3	—			
Western Kentucky U	3	16	5	—			
Western Maryland C	0	4	—	—			
Western Michigan U	2	15	1	0			
Western New England C	1	2	—	—			
Western Washington U	7	15	0	—			
Westminster C	0	3	—	—			
Wheaton C							
Illinois	6	4	—	—			
Massachusetts	3	4	—	—			
Wheeling Jesuit C	4	1	—	—			
Whitman C	0	2	—	—			
Whittier C	0	8	—	—			
Wichita State U	3	4	1	0			
Widener U	2	3	—	—	7	0	—
Wilkes C	5	1	—	—			
Willamette U	4	6	—	—			
William Paterson C of N.J.	0	4	—	—			
William and Mary, C of	26	6	5	—			
Williams C	3	19	—	—			
Winona State U	5	0	—	—			
Wisconsin, U of							
Eau Claire	2	4	—	—			
Green Bay	1	5	—	—			
LaCrosse	6	12	—	—			
Madison	22	4	10	47	85	9	13
Milwaukee	2	20	6	10			
Oshkosh	9	4	—	—			
Parkside	3	4	—	—			
Platteville	2	3	—	—			
River Falls	9	11	—	—			
Stevens Point	10	8	—	—			
Superior	0	4	—	—			
Wittenberg U	2	7	—	—			
Wooster, C of	4	14	—	—			
Worcester Polytechnic Institute	4	6	3	2	23	6	5
Wright State U	16	8	10	—			
Wyoming, U of	5	0	3	7	10	0	0
Xavier U	2	3	—	—			
Xavier U of Louisiana	0	25	—	—			
Yale U	0	11	21	30	1	0	7
Youngstown State U	10	39	3	—	a		
TOTALS	**3213**	**4437**	**1605**	**2131**	**3170**	**956**	**583**

Note: For brevity, "B.S." and "M.S." are used to denote all bachelor's and master's degrees, respectively, in each column. a Data not submitted. b Listed on basis of accreditation by AIChE-ABET. c The chemistry programs at Mount Saint Vincent and Manhattan College are integrated into a combined department with instruction in chemistry located at Manhattan College. d Saint Vincent College and Seton Hill College are integrated into a combined department. e UNC, Chapel Hill, Applied Curriculum in Chemistry degrees are combined with the chemistry department degrees.

Second group of 1991 ACS PRF grants approved

Acting on recommendations from the February meeting of the PRF Advisory Board, the ACS Board of Directors has approved 152 new or continuing ACS-PRF grants-in-aid. The board's action adds $4,095,505 to PRF commitments for 1991.

The new grants were recommended by the PRF Advisory Board from a total of 411 proposals. A third and final set of 1991 PRF grants will be announced this summer. Proposals for 1992 PRF grants are now being accepted. Applicants should note the revised limits for the scientific text of 4000 words for PRF Type AC and B proposals, and 1700 words for G proposals. For 1992 grants, the maximum salary and benefits that the principal investigator may receive each year will be increased to $5000, and the limit for travel will rise to $1000. Applicants from Ph.D. departments may request a $3000 supplement to involve an undergraduate in the research.

The "35th Annual Report on Research under Sponsorship of the Petroleum Research Fund" will be available in May. Individuals who wish a complimentary copy, or information and application forms for current ACS-PRF grant programs, should write Petroleum Research Fund, American Chemical Society, 1155—16th St., N.W., Washington, D.C. 20036, or call (202) 872-4481.

ACS-PRF Grants for Fundamental Research in the Petroleum Field (Type AC)

Alec M. Wodtke, U of California, Santa Barbara. State-Specific Effects on Intramolecular Vibrational Redistribution. $40,000

Viraht Sahni, City U of New York, Brooklyn C. Theory of the Inhomogeneous Electron Gas. $40,000

Joseph A. N. Zasadzinski, U of California, Santa Barbara. Electron Microscopy Investigation of Mechanisms of Vesicle Formation. $40,000

Jory A. Yarmoff, U of California, Riverside. Photon-Stimulated Desorption from Metal Halide Surfaces. $60,000

Richard J. Saykally, U of California, Berkeley. Measurement of the Electronic Spectrum of C_{60}. $40,000

Ti-Kang Kwei, Polytechnic U. Molecular Composites. $40,000

Thomas J. Kodadek, U of Texas, Austin. Mechanistic Studies of the Metal Porphyrin-Catalyzed Cyclopropanation of Alkenes. $40,000

Hugo Steinfink, U of Texas, Austin. The Crystal Chemistry and Physical Properties of Intergrowth Oxide Structures. $40,000

Edward C. Lim, U of Akron. Intermolecular Interactions in Aromatic Systems: the Structure and Dynamics of van der Waals Dimers, Excimers, and Bicimers. $40,000

David L. Freeman, U of Rhode Island. Solving Nonergodicity Difficulties in Classical and Quantum Simulations by J-Walking: Application to Cluster Alloys. $40,000

John H. Kennedy, U of California, Santa Barbara. Synthesis and Characterization of Conductive Glasses. $40,000

Andrew J. W. Gleadow, La Trobe U. Fission Track Thermochronology Studies of Post-Early Cretaceous Faulting, Uplift, and Unroofing of the Brooks Range, Alaska. $40,000

Geoffrey Davies, Northeastern U. Synthesis of Catalytic Alloys and Oxides. $40,000

Robert W. Murray, U of Missouri, St. Louis. Dioxirane Chemistry. $40,000

George C. Schatz, Northwestern U. Theoretical Studies of Molecular Photodissociation on Surfaces. $40,000

L. Neil Frazer, U of Hawaii, Manoa. Detection of Subsurface Fractures Using P-Wave Surface Seismic Data. $40,000

Brian E. Hanson, Virginia Polytechnic Inst. & State U. Solid-State Dynamics of Inorganic and Organometallic Solids. $40,000

Gerard Parkin, Columbia U. Synthetic and Mechanistic Studies of Electron-Rich Transition-Metal Complexes. $40,000

James A. Austin Jr., U of Texas, Austin. The Origin of the Southeastern United States Passive Continental Margin: Volcanic or Nonvolcanic. $40,000

Geraldine L. Richmond, U of Oregon. Comparative Studies of Single Crystal Surfaces in Solution and in UHV by Optical Second Harmonic Generation. $40,000

Arthur J. Ashe III, U of Michigan. Thermochromic Distibines and Related Compounds. $40,000

Mark A. Person, U of New Hampshire. Hydrologic Controls on Petroleum Generation within the Cooper and Eromanga Basins, Australia. $40,000

Jane E. G. Lipson, Dartmouth C. Polymer Solutions and Polymer Blends: a Theoretical Treatment of Compressible Mixtures Using Integral Equation Techniques. $40,000

John Weiner, U of Maryland. Experimental Studies of Cold and Ultracold Collision Dynamics. $40,000

James E. Barrick, Texas Tech U. Biostratigraphy of Silurian-Lower Devonian Strata, West Texas and Eastern New Mexico. $39,800

Renee D. Diehl, Pennsylvania State U. Defects on Metal Surfaces and Their Effects on Adsorbed Phases. $40,000

Jayanth R. Banavar, Pennsylvania State U. Flow-Through Porous Media. $40,000

David J. Bottjer, U of Southern California. Evaluation of Mesozoic and Cenozoic Cold Seep Faunas along the Northeast Pacific Convergent Margin. $40,000

Paul Knochel, U of Michigan. New Organometallic Reagents for Organic Synthesis. $40,000

Alexander J. Kresge, U of Toronto. Flash Photolytic Generation and Study of Reactive Species. $40,000

Charles H. DePuy, U of Colorado. Determination of Carbon-Hydrogen Bond Dissociation Energies in Simple Organic Molecules. $40,000

John S. Hutchinson, Rice U. Theoretical Studies of the Reactions and Spectroscopy of Highly Vibrationally Excited Molecules. $40,000

Douglas W. Stephan, U of Windsor. Early Metal Dithiolate Complexes: Macrocyclic Metalloligands. $40,000

Herbert Morawetz, Polytechnic U. Counterion Diffusion in Bulk Ionomers. $40,000

Timothy J. Bralower, U of North Carolina, Chapel Hill. Paleoceanography of the Early Cretaceous North Sea Basin. $40,000

Joseph M. O'Connor, U of California, San Diego. New Metallacycle Chemistry: Reactions with Carbenoid Reagents. $40,000

Donald W. Rogers, Long Island U, Brooklyn Center. Enthalpies of Hydrogenation. $40,000

David A. Kofke, State U of New York, Buffalo. A Novel Approach to Conformal Solutions. $40,000

M. Darby Dyar, U of Oregon. Detailed Crystal Chemistry of Iron-Bearing Phyllosilicates. $40,000

Edward R. Grant, Purdue U. Catalytic Reactions of Pulsed-Laser Prepared Organometallic Hydrides, Alkyls, and Carbonyls in the Gas Phase. $40,000

Thomas R. Dyke, U of Oregon. Structures of Aromatic Ring Van der Waals Complexes from Rotationally Resolved Infrared Spectra. $40,000

Timothy S. Zwier, Purdue U. Multiphoton Ionization Studies of Clusters of Immiscible Liquids. $40,000

Eric J. Amis, U of Southern California. Kinetics of Polymer Crystallization from Solution. $40,000

Hans-Rudolf Wenk, U of California, Berkeley. TEM Investigation of the Diagenesis of Silica Minerals. $39,770

Friedemann Freund, San Jose State U. Charge Distribution Analysis of MgO and CaO Catalysts Used in Oxidative Coupling of Methane. $40,000

Leslie J. Butler, Louisiana State U. Study of Zeolite Chemistry via NMR Imaging of Quadrupolar Nuclei. $40,000

Roger S. Macomber, U of Cincinnati. Synthesis of Molecules with Hidden Functional Groups. $40,000

James R. Chelikowsky, U of Minnesota. Theory of the Structural Properties of Semiconductor Clusters, Liquids, and Disordered Solids. $40,000

Bryant E. Rossiter, Brigham Young U. The Development and Investigation of Enantioselective Amidocuprate Reagents. $40,000

Michael F. Doherty, U of Massachusetts. Influence of Chemical Kinetics on the Design of Reactive Distillations. $40,000

William M. Reiff, Northeastern U. Donor-Acceptor Complexes of Iron Based on Fully Averaged, Mixed-Valent Aggregates with Novel Transport and Magnetic Properties. $40,000

Maitland Jones Jr., Princeton U. The Carboranylcarbene Rearrangement. $40,000

Marvin W. Rowe, Texas A&M U. Direct ^{129}I-^{129}Xe Dating of Petroleum. $40,000

Jose L. Martins, H. Ted Davis, U of Minnesota. Theory of Polymer-Metal Interfaces. $40,000

Robert Damrauer, U of Colorado, Denver. Gas-Phase Ion Molecule Studies on Aluminum-, Gallium-, and Silicon-Containing Anions. $60,000

Bruce E. Koel, U of Southern California. Chemisorption and Catalytic Reactions of Nitrogen Dioxide on Metal Surfaces. $40,000

Vemuri Balakotaiah, U of Houston. Spontaneous Ignition of a Coal Pile. $40,000

Thomas W. Scott, New York U. Time-Resolved Optical Harmonic Studies of Isomerization Dynamics at Interfaces. $40,000

Mark D. Hollingsworth, U of Alberta. A Scale of Functional Group Interaction Energies. $40,000

Paul J. Kropp, U of North Carolina, Chapel Hill. Surface-Mediated Electrophilic Additions. $40,000

Michael F. Herman, Tulane U. New Models for Polymer Dynamics in the Melt. $40,000

Edward L. Cussler, U of Minnesota. Pressure Swing Adsorption in Hollow Fibers. $40,000

David F. Kelley, Colorado State U. Interligand Electron Transfer in Transition-Metal Complexes. $40,000

Carl D. Hoff, U of Miami. The Heats of Binding of N_2, H_2, N_2H_2, N_2H_4, and NH_3 to Organomolybdenum Complexes. Thermochemical Models for Nitrogen Fixation. $40,000

Philip W. Choquette, U of Colorado. Origin of Porosity in Lime-Mud Dolomites. $39,935

Bruce H. Lipshutz, U of California, Santa Barbara. New Organometallic Chemistry of Al, Zr, Sn, and Cu. $40,000

Joseph L. Templeton, U of North Carolina, Chapel Hill. Chiral Transition-Metal Reagents for Organic Syntheses. $40,000

ACS-PRF Grants for Fundamental Research in the Petroleum Field (Type B)

Tami I. Spector, U of San Francisco. Synthesis and Investigation of Strained Cycloalkene Anions. $20,000

William J. Middleton, Ursinus C. New Methods and Reagents for Introducing Fluorine into Organic Molecules. $20,000

Kenneth Turnbull, Wright State U. Routes to, and Transformations of, Thionosulfites and Their Analogs. $20,000

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Ralph E. Sturgeon, on behalf of FACSS. Atomic Spectroscopy, 18th Annual Federation of Analytical Chemistry and Spectroscopy Societies Meeting, Anaheim, Calif., October 1991. $2000

Alison Butler, on behalf of the Regents of the U of California. Bioinorganic Chemistry of the Less Familiar Elements: Applications to the Marine Environment, ACS national meeting, New York City, fall 1991. $2000

Richard L. Martin, on behalf of the ACS Division of Physical Chemistry. New Developments in Superconductivity, ACS national meeting, New York City, fall 1991. $1000

Robert Tycko, on behalf of the ACS Division of Physical Chemistry. New Davelopments and Applications of Magnetic Resonance and Optical Spectroscopies, ACS national meeting, New York City, fall 1991. $1000

Mark D. Hollingsworth, on behalf of the U of Alberta, Canada. Chemistry of the Organic Solid State, 10th International Conference of the Chemistry of the Organic Solid State, Vancouver, British Columbia, Canada, July 1991. $2000

Jonathan L. Sessler, on behalf of the U of Texas, Austin. Bioinorganic Chemistry and Molecular Design, ACS national meeting, San Francisco, spring 1992. $2000

Henk L. C. Meuzelaar, on behalf of the U of Utah. Pyrolysis of Natural and Synthetic Macromolecules, ACS national meeting, Atlanta, spring 1991. $2000

William C. Stwalley, on behalf of the U of Iowa. Laser Science, 7th Interdisciplinary Laser Science Conference, Monterey, Calif, September 1991. $2000

Ripudaman Malhotra, on behalf of the ACS Division of Fuel Chemistry. Liquefaction Mechanisms, ACS national meeting, Atlanta, spring 1991. $2000 Mtg., Atlanta, April 1991. $2,000

Lance E. De Long, on behalf of the U of Kentucky Research Foundation. Rare Earth, 19th Rare Earth Research Conference, Lexington, Ky., July 1991. $2000

Martha K. Turckes, on behalf of ACS Project SEED. ACS Project SEED—Supplementary Program. $16,000

Terry A. Miller, on behalf of Ohio State U Research Foundation. Free Radicals, 21st International Free Radical Symposium, Williamstown, Mass., August 1991. $2000 □

ACS on indoor air pollution, other issues

ACS recently sponsored a special briefing for members of Congress and their staffs on issues and policies affecting indoor air pollution and transmitted its views on a number of current issues to Congress and certain regulatory agencies.

For the briefing sponsored in conjunction with the Congressional Environmental & Energy Study Conference, ACS provided four speakers to present scientific, technical, and engineering concerns relating to indoor pollution. They included Joan Daisey, director of the Indoor Environment Program at Lawrence Berkeley Laboratory, who discussed the scientific background for indoor air contamination. John Spengler, professor of the Harvard School of Public Health, reviewed what is known about the health effects of indoor air pollution, emphasizing that indoor air is different than outdoor air.

Jonathan Samet, chief of the pulmonary and critical care division at the University of New Mexico Department of Medicine, gave examples of known health problems from indoor air contamination and how carefully the issue must be examined to avoid health problems. Finally, Paul Cammer, president of the Business Council on Indoor Air, reviewed the building industry's perspective, which holds that most health problems are from biological factors such as mites and molds and that better maintained and operated building systems would solve many illnesses.

ACS sponsored the briefing because Congress has taken a very active interest in indoor air pollution this year, concentrating on the possibility that chemical contamination from construction and household products may be responsible for many complaints. Bills in the House (H.R. 1066) and the Senate (S. 455) would direct the Environmental Protection Agency to begin research programs on the sources and effects of indoor contaminants, among other provisions.

In a related matter, ACS urged EPA to consider nontraditional approaches in developing regulations defining laboratories as a "source" category as required by the Clean Air Act. The society suggests that each laboratory be required to draw up and adhere to an emission control work plan.

The plan, according to ACS, should outline procedures to minimize evaporation of chemicals, aerosol production, and particulate release. In addition, it should include a record of employee training and a regular internal evaluation program to ensure compliance and continued improvement in the reduction of emissions.

On the budget front, ACS told the House Subcommittee on Energy & Power that the Department of Energy's fiscal 1992 requested cut of 19% to $40 million for its six advanced coal research programs "would be disastrous." Cutting the programs seems to be directly counter to the actions required to fulfill the Administration's National Energy Strategy's goals for developing alternative fuels and finding environmentally sound ways to utilize the nation's vast coal reserves. ACS recommended that the coal research budget be set at a minimum of $60 million for 1992. In addition, the society recommended establishment of a $5 million competitive program for fundamental oil shale R&D.

The balance that needs to be struck between funding for space station *Freedom* and science-related programs at the National Science Foundation, EPA, and even the National Aeronautics & Space Administration, was addressed by ACS in a letter to the chairmen of the House and Senate appropriations' subcommittees that must make those decisions. The society made the point that in an era of fiscal constraint, any resources allocated to the space station should support important life sciences research, which has been identified as the station's primary objective. Further, ACS said it strongly believes that planned microgravity experiments on the station might be better and more economically completed on Earth or during Spacelab missions.

ACS also told the two chairmen, in a separate letter, that the proposed 13% increase for the EPA's Office of

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JUNE 3, 1991

CHEMICAL & ENGINEERING

NEWS

Indirect cost controversy puts universities in the hot seat
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Stanford's Carl Djerassi wins 1992 Priestley Medal

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CHEMICAL & ENGINEERING
NEWS
JUNE 3, 1991

Volume 69, Number 22
CENEAR 69 (22) 1–48
ISSN 0009-2347

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- **Spacecraft Magellan completes first cycle of radar mapping of Venus, providing scientists with impressively detailed pictures of the planet.** Page 5
- **President Bush outlines proposal to rid Mideast of weapons of mass destruction and to stem buildup of conventional weapons.** Page 5
- **Recent Congressional approval of "fast-track" approach to trade negotiations is good news for U.S. chemical industry.** Page 6
- **National Institutes of Health seeks coinventor status for AIDS drug AZT, will support Barr Laboratories in its bid to market generic form of the drug.** Page 6

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Business

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Reunification has given boost to Germany's chemical industry, especially specialties and consumer products sectors, according to industry association's president. **Page 13**

Government

Rumblings over how universities handle indirect costs of research have led to Congressional hearings, drafting of legislation. **Page 17**

Published estimates of toxic chemical emissions by industry provide occasion for environmentalists to complain about how seriously the environment continues to be contaminated. **Page 20**

Science/Technology

Opportunities and challenges for catalytic chemistry are stressed in National Research Council report previewed at recent Catalysis Society meeting. **Page 23**

New insights into behavior of monolayers on surfaces are provided by scanning tunneling microscopy. **Page 26**

Discovery of novel bimetallic yttrium-copper complex may lead to easier fabrication of some superconductor materials. **Page 27**

Books

"Technological Risk" by H. W. Lewis offers reader-friendly assessment of the broad subject, but falls down in its discussion of political players involved. **Page 32**

Priestley Medal

Carl Djerassi, a chemistry professor at Stanford University, will receive ACS's 1992 Priestley Medal in recognition of his contributions to chemistry and society. **Page 28**

Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036
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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
Robert H. Marks, Director, Publications Division

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Subscription Rates 1991: Printed editions: nonmembers U.S. 1 yr. $95, 2 yr. $171; outside U.S. 1 yr. $131, 2 yr. $243. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $12. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management: CENTCOM LTD.
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LETTERS

Fruitful collaboration

Rudy Baum's article highlighting a Division of Medicinal Chemistry symposium at the ACS Atlanta meeting on the mode of action of anticancer drugs (C&EN, May 6, page 31) failed to cite an important point mentioned in my presentation. The long and fruitful collaboration between JoAnne Stubbe of the department of chemistry at Massachusetts Institute of Technology and me has been an essential component in our mechanistic unraveling of the action of bleomycin on DNA. As most researchers in the field are well aware, our decade-long interaction on this problem has been a most productive one as evidenced by our joint publications on this and related topics.

Since I did not have the opportunity to review the article before publication, I hope this letter will set the record straight and permit Stubbe, me, and our research groups to share the generous recognition in Baum's article.

John W. Kozarich
Professor of Chemistry and Biochemistry
University of Maryland, College Park

Fast-track trade agreement

The U.S. chemical industry applauds Congress for recently extending President Bush's "fast-track" trade agreement negotiating authority beyond June 1, 1991. That action—which culminated an intense legislative debate—lays the groundwork for continuing two very important international trade negotiations that could have a long-term, positive effect on the chemical industry.

Essential for trade negotiations, fast-track allows the President to negotiate bilateral or multilateral trade agreements with the understanding that Congress has only two options as concerns the negotiated terms. Congress can either approve or disapprove the trade agreement in its entirety. The agreement cannot be picked apart. Without it, other countries would not spend years negotiating a treaty with the U.S., knowing that the individual terms would later be amended by Congress.

Now that Congress has extended fast-track authority, trade negotiations can proceed on both sides of the Atlantic. A successful Uruguay round of the General Agreement on Tariffs & Trade (GATT) under negotiation in Geneva could expand the access of U.S. companies to markets around the world. The chemical industry will be working with the GATT negotiators to provide increased market access for chemical exports, increased global protection for our intellectual property, and fair treatment of our growing foreign investments.

Fast-track extension also opens the way to begin negotiations on a North American Free Trade Agreement (NAFTA) that will bind the U.S., Mexico, and Canada into a trade union larger than the European Community. NAFTA will have a buoyant effect on the economies of all three nations. In particular, it will accelerate Mexico's growth into a market-oriented economy that will create growth markets for our chemical exports as well as new investment opportunities for our companies.

The U.S. chemical industry strongly believes that if NAFTA is successfully negotiated, it could be very beneficial to all parties. From a chemical industry perspective, we are encouraging our trade negotiators to seek phased elimination of bilateral tariffs, greater foreign participation in Mexico's petrochemical industry, guaranteed intellectual property protection, and removal or reduction of export subsidies. The industry also supports the negotiation of a parallel agreement that would elevate Mexico's environmental compliance enforcement to a par with that of Canada and the U.S.

A successful NAFTA will create an attractive investment environment in Mexico. Industry that might have been established in Southeast Asia today, would more likely be situated in Mexico tomorrow—if NAFTA becomes a reality. The resulting economic growth would stimulate Mexico's purchase of additional U.S. products and services. Already, 70% of Mexico's imports of goods and services originates from the U.S. Without NAFTA, more of the new plants would be built in Asia. The host countries and Japan would benefit, not Mexico and the U.S.

For the chemical industry, a free trade agreement that includes Mexico will be a positive step as we continue to meet the challenge of international competition. It will help Mexico develop into a modern market-oriented economy. It will give U.S. chemical exports clearer access to that growing economy. And it will greatly increase the size of what we call our home market, allowing us to build larger, more economical, and more efficient plants both in the U.S. and in Mexico. However, the extension of fast-track only gets us to the negotiating table, where the work will really begin. The chemical industry will have to actively participate in the NAFTA negotiations through our private-sector advisers and trade groups. If we are successful in

Use of Specialty Food Additives To Continue To Grow

Convenience foods, health concerns are driving growth in demand for chemicals and materials used as food additives, replacements

Ann M. Thayer,
C&EN Northeast News Bureau

Few processed foods can be found that do not contain one or more of the thousands of different chemicals and materials that are food additives. According to recent estimates, about $5.5 billion worth of additives are used widely in the $385 billion U.S. food and beverage market. Throughout the 1990s, the U.S. market for food additives is expected to grow 4 to 6% annually—to as much as $7 billion by 1995.

The development and use of food additives is frequently driven by consumer demand and often becomes a balancing act between consumers' seemingly contradictory desires—the desire for more "natural" foods versus that for prepared, often microwaveable, convenience foods. The situation is complicated further by the desire for low-calorie, low-fat, and low-cholesterol foods.

Health concerns and the desire for convenience foods will drive market growth for food additives, particularly for new products such as high-intensity sweeteners and fat replacers. The impact of these trends on markets and developments in food chemicals was the focus of a session sponsored by the Division of Chemical Marketing & Economics at the recent ACS national meeting in Atlanta.

Companies involved in the production of specialty chemicals as food additives have been estimated to number in the hundreds, ranging in size from large chemical manufacturers such as Dow, Monsanto, W. R. Grace, and Hercules, to small specialty flavor or color producers.

But only a few hundred food additives account for more than 90% of market volume, says Newman H. Giragosian, president of Delphi Marketing Services in New York City. And, according to the consulting firm SRI International, fewer than 10 chemicals have a market value over $40 million. Only aspartame is sold in any appreciable volume (more than 5 million lb) at a price above $20 per lb. Since food additives are used in small amounts, most are sold in small volumes, are priced on a performance basis, and fall into niche markets.

The fragmented market is viewed most easily from either an additive's function or its end use. Additives in foods act as sweeteners, flavors, colors, thickeners, emulsifiers, acidulants, antioxidants, nutrients, and preservatives. Processed food markets using additives vary from soft drinks to alcoholic beverages and from meats, poultry, seafood, and dairy products to baked goods.

As the demand for prepared or processed foods increases, so too will the demand for food additives, says Giragosian. But the industry faces problems, he explains, such as increased "consumerism" based on greater knowledge about additives, which can result in negative publicity and negative connotations for additives, and a movement toward "natural" foods. Coupled with increased government regulation, high R&D and regulatory approval costs, and longer times to reach commercialization, he adds, these factors can negatively affect growth.

Because of the nature and dynamics of the industry, these factors won't affect all categories of food additives equally. Opportunities exist for new materials considered healthier or those that replace additives that are suspected health hazards. Mature markets with limited differences between competing products such as vitamins, thickeners, emulsifiers, antioxidants, and preservatives are not expected to show so much growth as is expected for nonnutritive sweeteners, fat substitutes, and flavoring agents.

Although dominated for several years by aspartame (*N*-L-α-aspartyl-L-phenylalanine 1-methyl ester), the sweetener market is expected to continue to grow, some estimate by as much as twice the rate for the overall market for food additives. A significant event will be the expiration of NutraSweet Co.'s U.S. patent on aspartame in mid-December 1992. NutraSweet, a wholly owned subsidiary of Monsanto, has about 98% of the dollar value of U.S. sales for sweeteners, according to a 1990 study by the consulting firm Frost & Sullivan. This is expected to drop below 50% as other products are approved by the Food & Drug Administration.

Stability, taste, and safety are primary competitive factors. Improvements in these areas will allow sweeteners to find use in an even wider range of food types. Better heat stability would offer a sizable advantage and reduce demand for saccharin which, although it can be used in cooking and baked goods, has had limited use because of its unpleasant aftertaste. Liquids make up about 70% of the sweetener market and dry foods the remaining 30%.

Although the expiration of NutraSweet's patent may bring down prices, as it has in Europe, new higher intensity sweeteners to compete with aspartame also may be high priced. However, many sweeteners show a compounded effect when used together, thereby reducing the amount needed. Approved in 1988 and gaining some market share is Hoechst Celanese's acesulfame-K. Other possible near-term products awaiting approval are sucralose, codeveloped by Tate & Lyle and Johnson & Johnson, and alitame, developed by Pfizer.

Food additives' sales to grow

$ Millions	1990[a]	1995[a]	Annual change 1990–95
Sweeteners	$1000	$1310	5.5%
Gums/thickeners	864	1100	4.5
Flavors/enhancers	600	785	5.5
Emulsifiers	460	515	2.3
Acidulants	246	287	3.1
Colors	220	272	4.3
Vitamins/nutrients	157	177	2.4
Enzymes	143	169	3.4
Preservatives	83	92	2.1
Antioxidants	24	27	2.4
Fat mimics	na	na	—
Other	500	585	3.2
TOTAL	$4317	$5319	4.3%

a Estimated. Source: Delphi Marketing Services

Acesulfame-K is the potassium salt of 6-methyl-1,2,3-oxathiazin-4(3H)-one 2,2-dioxide, marketed under the tradename Sunette. It is about 200 times sweeter than sucrose, and noncaloric. According to the company, it has a long shelf life and is stable when exposed to heat, the lack of which are considered shortcomings of aspartame. FDA approval is food-type specific, and to date it has been approved for use in dry beverage mixes, chewing gums, desserts, and tabletop uses. Thus it is not yet competing with aspartame in beverages.

Sucralose is a chlorinated sucrose derivative, about 600 times as sweet as sucrose, which does not break down in the body. Like aspartame, alitame (L-α-aspartyl-*N*-(2,2,4,4-tetramethyl-3-thietanyl)-D-alaninamide) is amino acid based. It is said to be 2000 times sweeter than sucrose and partially metabolized, with a minimal number of calories. In addition to alitame, Pfizer has capacity to produce more than 50 million lb of polydextrose, a low-calorie bulking agent used to replace sugar and some fat.

Along with the desire for low-calorie foods, the demand for low-fat foods is expected to lead to rapid growth in the market for fat substitutes and mimetics. Sales of low-fat and low-cholesterol processed foods are estimated to grow from $28 billion at the end of 1991 to almost $33 billion in 1993, says Joanne Kennedy, technical service representative from Stepan Co., a specialty chemicals manufacturer. Figures from the U.S. Department of Agriculture's *National Food Review*, she adds, show there is potential to replace more than 16 billion lb of fat used in cooking, baking, and frying, or found in dairy items such as cheese, butter, ice cream, and yogurt.

Fat replacement products and technologies are being developed by many firms, she explains. These can roughly be divided into two categories—synthetic fat substitutes and fat mimetics. "Synthetic fat substitutes are nondigested, noncaloric fat replacers that are molecularly like a fat," she says. Substitutes must function similarly to fats, be nontoxic, and have any metabolites completely excreted while not draining the body of vitamins or nutrients.

"This whole area will be slow to develop," says Kennedy, "because of safety questions." Unlike most food additives, fat substitutes could represent up to one third of a person's daily caloric intake. "Usually, an additive's acceptable consumption level is determined by testing high dosages, 100 times or more than normal. How do you feed a rat that much fat?" she says. To be competitive as one-to-one replacements for fat, they also must be reasonably priced and consistently available.

Aspartame sweetener is single largest product

$ Millions	1990 sales[a]	Function
Aspartame	$ 750	Sweetener
Vanillin/ ethyl vanillin	160	Flavoring
Citric acid	160	Acidulant
Monosodium glutamate	75	Flavor enhancer
Xanthan gum	50	Thickener
Sorbates	55	Preservative
Carrageenan	45	Thickener
Caramel	40	Colorant
TOTAL	$1335	

a Estimated. Source: SRI International

A synthetic fat substitute developed by Procter & Gamble is Olestra, a sucrose polyester that is noncaloric and also cholesterol-free. With similar properties to edible fats, says Kennedy, Olestra was submitted in 1987 to FDA for approval in replacing up to 35% of the fat in home-use shortenings and oils, and up to 75% of fat in commercial frying applications.

Other synthetic fat substitutes under development, says Kennedy, include DDM, a fatty alcohol ester of malonic and alkyl malonic esters from Frito-Lay; EPG, propylene oxide derivatives from Arco Chemical; and TATCA, tricarballic acid esterified with fatty alcohols from CPC International. Other than through extraction or drying methods, she explains, fat removal or replacement in frying is not now possible since nonnutritive heat-transferring oils are not yet available.

As another category of fat replacers, fat mimetics cover a broad range of materials and mimic the "mouth feel" of fat. Being carbohydrate- or protein-based, they have at most 4 calories per gram, says Kennedy, as compared with nine for fats. They generally differ from fat substitutes by being less expensive and are not used across the board as one-to-one replacements. Instead, they are used at relatively low levels of 10 to 50% to bind water.

Starch-based products form bland gels with fatlike textures. Commercial specialty starches include potato, corn, and tapioca maltodextrins produced by Avebe, GPC, and National Starch & Chemical, respectively. Although these have been used for some time in baked goods, frozen desserts, and dressings, a newer product is Oatrim, a β-glucan amylodextrin. Oatrim was developed by the USDA's Regional Research Laboratories in Peoria, Ill., and has been licensed to Rhône-Poulenc and Con Agra.

Microparticulated materials can also mimic fats, but tend to be more expensive, says Kennedy. Simplesse, made by a subsidiary of Monsanto, was approved in early 1990. It is egg and milk proteins, heated and sheared to form spheres 0.1 to 2 μm in size. Protein particles this small are perceived by the tongue as feeling creamy. Initially, the company developed its own Simplesse-based food product and entered the superpremium ice cream market.

According to the company, its frozen dessert products have a 19% share overall in the superpremium category and hold the leading market share, 34%, of fat-free brands in 70% of the U.S. in which the product was launched. By targeting only the fat-free market at first, says a company representative, Simplesse could be introduced in a product labeled as natural. Recently, a fat-free and sugar-free frozen dessert containing Simplesse and NutraSweet was launched.

Monsanto is looking for FDA approval to expand Simplesse into other areas such as salad dressing, cheese, yogurt, mayonnaise, and margarine. Although it can now be formulated to avoid breaking down at high temperature and used in baked goods or melted cheeses, says Kennedy, it cannot be used like a cooking oil to transmit heat. Kraft is reported to have a protein-based product similar to Simplesse, called Trailblazer, currently before FDA for review.

Less expensive water-soluble carbohydrate gums and other materials can bind water and replace fat. These include guar, xanthan, and locust bean gums; pectin; and carboxymethylcellulose. FMC has a product called Avicel that is a microcrystalline cellulose gel. The firm has worked with food processors to use it in low- or no-fat ice creams, salad dressings, bakery products, and cheeses. Another product, by Alpha-Beta Technology and not yet approved, is a microspherical β-glucan fiber derived from yeast.

One of the best known thickeners is carrageenan, a seaweed-derived hydrocolloid. FMC's Marine Colloids business group is a major producer of carrageenan, which is used to thicken, gel, and stabilize foods.

Soft-drinks market uses most additives

$ Millions	Sales 1982	Sales 1989	Sales 1994	Annual change 1989–94
Soft drinks	$ 205	$ 728	$1170	10.0%
Sauces, dressings, oils	272	432	675	9.3
Meat, poultry, seafood	211	330	455	6.6
Dairy products	187	285	415	7.8
Baked goods	159	273	395	7.7
Processed, frozen foods	82	148	220	8.3
Grain mill products	68	108	150	6.8
Alcoholic beverages	34	53	70	5.7
Other	123	206	350	11.2
TOTAL	$1341	$2563	$3900	8.8%

Source: Freedonia Group

Hercules is also a producer. McDonald's uses carrageenan in its new lean hamburger formulation to hold the meat together and retain moisture through cooking. Carrageenan or starch formulations also are used in poultry products, hot dogs, sausages, and dairy products.

Fat replacers are a good example of how the use of additives in food necessitates the development of flavor additives. Although fat substitutes or mimetics may give the look and feel of fat, they usually do not carry or add the flavors that might develop from cooking or browning. Similarly, sugar not only is part of fermentation in beverages and breads but it also adds bulk, texture, and flavor that may be lacking with nonnutritive sweeteners.

"The flavor industry can look forward to continued growth," says Don Birtwistle, president, McCormick & Wild, a food flavorings joint venture. "Basically, any factor that increases the need for processing or the designing of foods to meet specific needs is likely to call upon flavors to build in consumer appeal for the product." Growth is expected as a result of the need for flavor stability and retention through the freezing and thawing of processed prepared foods, especially those packaged for microwaving.

Another factor in this growth has been an increased demand for natural flavors, he adds. The market for natural fruit flavors is expected to grow at 7 to 8%, whereas artificial flavors will grow at 2 to 3%. Artificial flavors tend to be more powerful and lower in cost than natural equivalents and thus natural flavors can have a difficult time competing with synthetic versions. However, new technologies are providing the means to produce highly concentrated natural flavors, says Birtwistle, and the higher cost is seen as well worth the increased consumer appeal of a natural product.

Flavor additives can be roughly divided into two categories, explains Birtwistle. One class is flavorings consisting of raw materials or natural products used as the source of flavor. Examples are mint oils and vanilla. A second class is compound flavors that often are mixtures of key synthetic chemicals used to achieve a particular flavor profile. These are designed by deciphering flavor components to reproduce standard or familiar flavors.

The compound flavor market is estimated at $600 million for 1990, says Birtwistle, and is expected to grow at a rate of 6 to 8% per year. Sales are almost equally divided between fruit flavors, $330 million, and other flavors, $270 million, which include dairy, vegetable, meat, poultry, fish, and sweet flavors. The market can also be divided between natural, 60%, and artificial flavors, 40%.

Aroma and flavor chemicals, of which there are 1500 to 1800, are used in a broad range of processed products, which cover almost the entire food and beverage industry, as well as in personal care and tobacco products. Flavors are manufactured using several different technologies by flavor houses—which usually are privately held or subsidiaries of larger, publicly held companies. Historically, the industry has been self-regulated.

A subclass of compound flavors are reaction or process flavors in which a mixture of ingredients may be heated to produce desired chemical reactions and mimic a flavor. To produce savory flavors such as those found in meat, selected mixtures of proteins, amino acids, fats, and carbohydrates are heated to simulate the cooking process. Similarly, enzymatic reactions are used to reproduce cheese flavors. The recent introduction of surimi, which is based on fish protein, has increased the demand for seafood flavors. Most efforts have focused on extractions of flavors from fish, shellfish, shells, and seaweed.

Unlike the flavor industry, the food color business is a small, highly regulated industry. Producers of food, drug, and cosmetic colors in the U.S. include Crompton & Knowles, PMC, and Warner-Jenkinson. Yet like other additives, marketing trends will be toward the use of natural products, says Harry N. Meggos of Warner-Jenkinson Co. Colors serve both an aesthetic function and as a means of identification, since connections are made between colors and flavors.

Colors fall into two main categories—certified colors, which are synthetic compounds of known structure whose production is regulated by FDA, and exempt colors, which are natural colors derived from animal, vegetable, or mineral sources or their synthetic duplicates. After a period in the 1970s when many colors were banned because of fears of their being unsafe, the number of certified colors has dropped from a high of about 20 in the 1950s to six, explains Meggos—red No. 40, blue No. 1 and 2, green No. 3, and yellow No. 5 and 6.

Sales of food colors are estimated at $250 million with synthetics accounting for less than $100 million, says Meggos. In 1990, 8.4 million lb of industrial certified food colors were sold. Growth has been around 1% over the past few years and is expected to continue at that level into the 1990s. Natural colors are expected to show much higher growth as a result of market pressures.

Common colors exempt from certification are often extracts from seeds, roots, and vegetables such as turmeric (yellow), annatto (orange/red), and paprika (red). Although found in plants, a synthetic form of beta carotene (orange/red) is used most often and is exempt. Cochineal, a very expensive red color at $150 to $200 per lb, is based on an extract from insects. Already used in cosmetics, it is finding increased use in foods to replace synthetic red colors. Two other frequently used exempt colors are caramel, from burnt carbohydrates, and titanium dioxide, from mineral sources.

A problem with natural colors is their stability, says Meggos, as they are sensitive to pH, light, and heat. With low tinctorial strengths when compared with synthetic colors, 10 to 50 times more of a natural color may be required. Although not all categories of foods may contain colors, he adds, U.S. regulations allow their use in unlimited amounts, but generally less than 100 ppm is needed. But, because these materials come from natural sources, they tend to be higher in price and subject to uncertain supply conditions, making widespread use, while desirable, less likely.

Most other food additive categories are relatively mature and growth rates of only 2 to 3% are expected. One of the slowest growing is the emulsifier market, although it accounts for a large share of food additive sales. The food industry is estimated to use about 250 million lb of surfactants, says Connie M. Hendrickson, director of Ar'kon Consultants in Dallas. However, surfactants make up one of the smallest percentages of "inactive" ingredients in foods.

Surfactants as food additives act as emulsifiers, defoamers, and wetters in food processing. Generally, nonionic forms are used because they are easier to handle and more predictable to work with than other surfactant types, says Hendrickson. Used to make two phases miscible, emulsifiers stabilize and homogenize processed foods and prevent the formation or aggregation of particles. In preventing sedimentation, they can prolong a product's stability and shelf life. Emulsifying agents modify texture and rheological properties, and prevent foam formation in processing.

Phosphates as food additives can also act as emulsifiers in dairy and dessert products. About 67 million lb of phosphates were used in the U.S. food industry in 1990. In bakery products such as mixes and doughs, phosphates function as chemical leavening agents. Protein modification and sequestration are this additive's major functions in meats such as ham, luncheon meats, bacon and sausages, and in poultry and seafood. Cheeses, puddings, coffee creamers, and whipped toppings also contain phosphates as protein modifiers and sequestrants. In cola beverages, phosphoric acid is used as an acidulant and flavor enhancer.

Food additives must show demonstrable safety in animal studies and are granted GRAS (generally recognized as safe) status by FDA. Standards of identity also affect many processed foods where regulations control the amount, if any, allowed of certain food additives. Although there are a few very profitable specialty food additives, new products must compete in performance and price with many already satisfactory and approved products. Large R&D investments, along with high costs and long delays in required regulatory approval, can be disincentives and barriers to market entry. "In this environment, it is estimated that fewer than 10 novel chemical entities have received approval by FDA as direct food additives in almost two decades," says Nicolo Bellanca, a senior consultant from SRI International.

"The major influences on the industry," he explains, "include the existing food safety and labeling regulations, the changing likes and dislikes of consumers, and the needs of food processors." Interactions among the needs of these groups shape a number of key issues whose overall impact on the food additives business may vary in intensity and over time. "Most commercial development efforts in food additives appear to focus almost exclusively on the functional areas that offer the potential for regulatory approval of one or two additional products by 1995," says Bellanca. □

Controversy over Indirect Costs of Research Has Universities Squirming

Disclosures that taxpayers' funds have been spent on frills rather than intended research has triggered hearings and investigations in Washington

Pamela S. Zurer, C&EN Washington

In Washington these days there's no escaping the controversy over the indirect costs of research. Revelations that universities have spent taxpayers' funds on frills rather than the research they were meant to support has made the issue a hot political topic.

Congress is holding hearings, conducting investigations, and drafting legislation. The White House Office of Management & Budget is revising its accounting guidelines.

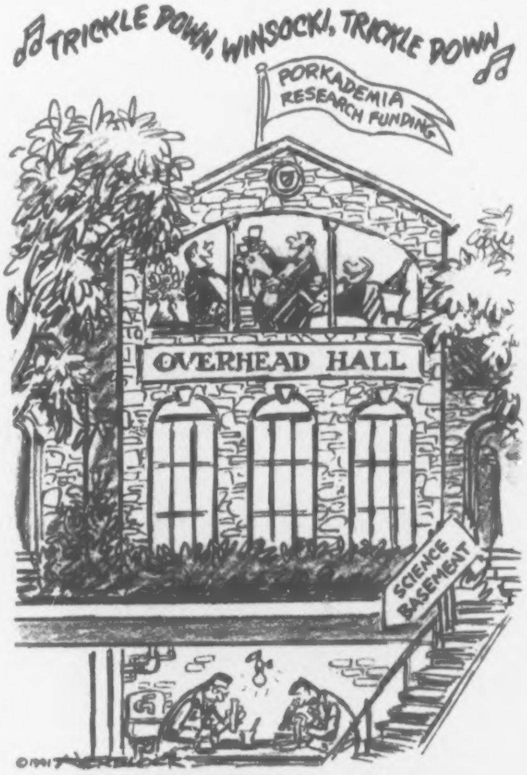
A task force within the Department of Health & Human Services is pondering the issue, while the Department of Defense reviews its policies. University officials and their Washington representatives, meanwhile, are trying to shift the focus from accounting scandals to the need for systematic reform in research funding.

It may take a year or more before the implications for the research community of all this frenetic activity become clear. But even now it's apparent the current methods of dividing the research funding pie between scientists and university administrations are on the way out.

Indirect costs are the monies universities take from research grants and contracts to cover expenses that can't be assigned to a specific project. For example, equipment, materials, and individual research workers' salaries easily can be pegged to a particular grant or grants.

However, other costs such as maintenance, building depreciation, utilities, and salaries of administrators to keep things running are trickier to handle. In the years since World War II, the federal government and research institutions have developed a system to handle those indirect costs.

Briefly, expenses not classified as direct charges are allocated to various cost pools—general or departmental administration, library, operation and maintenance, and the like. Then a determination is made as to what percentage of each pool supports research as opposed to other university functions. A weighted average of those percentages, negotiated each year for each university, then is charged against research grants as the indirect-cost recovery rate. It's that system that's now under the microscope.


TRICKLE DOWN, WINSOCKI, TRICKLE DOWN
PORKADEMIA RESEARCH FUNDING
OVERHEAD HALL
SCIENCE BASEMENT
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Scientists, while recognizing indirect costs as a necessary evil, have never liked losing control over a substantial portion of the research funds they bring into the university.

"By and large operating scientists always feel overhead is too high, no matter how low the rate might be," says Paul Gassman, chemistry professor at the University of Minnesota. Gassman, immediate past-president of the American Chemical Society, stresses his opinions are his own and not official ACS policy.

In recent years, as indirect-cost recovery rates have climbed above 60% and 70% at some major universities, the chorus of complaints has grown louder. Sharp protests by Stanford University faculty caught the attention of Rep. John D. Dingell (D.-Mich.), forceful chairman of the House Energy & Commerce Committee.

Last fall Dingell asked Congress' General Accounting Office, as well as staff investigators from the Investigations & Oversight Subcommittee he also chairs, to look into Stanford's accounting. Also on the hot seat was the Office of Naval Research (ONR), the Defense Department agency with the responsibility for negotiating indirect costs and overseeing federal funds at Stanford.

The results have proved both embarrassing and expensive to Stanford. At a hearing before Dingell in March, Stanford officials lamely tried to explain away mischarges and overcharges throughout the 1980s—including the university yacht, antique furniture, and flowers for the president's house. A GAO auditor claimed they could total as much as $200 million (C&EN, March 18, page 4).

ONR auditors also came in for scathing criticism from Dingell, who asserted they had been asleep at the switch. In the aftermath, ONR has unilaterally cut Stanford's provisional indirect-cost rate to 50%—a step that could cost the university $20 million a year (C&EN, May 6, page 26).

Dingell's scrutiny set off an explosion of activity. While GAO and the Dingell committee continue their probes, ONR has asked the Defense Contract Audit Agency to audit all 41 universities whose research funds the Defense Department is responsible for overseeing. HHS, which oversees the majority of research institutions, has announced plans to audit the 20 largest this year. And universities have initiated their own reviews in hopes of heading off uncomfortable revelations.

Nevertheless, titillating tidbits continue to surface. At a second hearing Dingell convened in May, HHS revealed among other items that Dartmouth University had been charging the federal government for its president's chauffeur; Cornell University for chartered aircraft for its president; and the University of Pittsburgh for a trip to the Grand Cayman Islands by its president's wife.

"I believe that universities now understand that this is a new day and that all overhead charges they make to the government must relate to government-funded research rather than merely support a country-club life-style," Dingell said. "Taxpayer dollars must support research—not receptions—and scientists—not sailors."

HHS inspector general Richard P. Kusserow testified he believes the system has evolved so that the scientific raison d'être of indirect cost reimbursement has gotten lost. "It's become a whole other world with accountants playing games on paper," he says.

Kusserow says at least some of the problem stems from OMB Circular A-21, the guidelines on cost accounting at educational institutions, which is so unspecific it encourages constant wrangling. "Unfortunately, the way the system operates it invites gamesmanship. It invites an attitude of 'We [the university] will put as much as we can in the indirect cost pools and you [government auditors] see if you can find it.' "

Indirect cost rates vary widely at top R&D universities

	Cognizant agency[a]	Total federal R&D funds[b] ($ millions)	Indirect cost rate[c]
Stanford U	DOD	$239.8	72%
Johns Hopkins U[d]	HHS	211.9	65
Massachusetts Institute of Technology	DOD	207.2	58
U of Washington	HHS	203.7	53
U of California, Los Angeles	HHS	170.8	48
U of Michigan	HHS	167.9	59
U of California, San Diego	HHS	166.6	49
U of California, San Francisco	HHS	159.0	38
U of Wisconsin, Madison	HHS	150.5	44
Columbia U	DOD	150.3	74

Note: DOD is Department of Defense, HHS is Department of Health & Human Services. a The cognizant agency for each university is responsible for overseeing R&D funds from all federal agencies. b Fiscal 1989. c Ratio of indirect costs to direct costs less exclusions. d Excludes Applied Physics Laboratory. Source: Department of Health & Human Services

At HHS, Kusserow, NIH Director Bernadine P. Healy, and HHS assistant secretary for management & budget Kevin P. Moley have formed a working group to examine the costs of research in general and indirect costs in particular.

At OMB, director Richard Darman already has set in motion changes to Circular A-21. "Recent information shows abuses in reimbursements claimed by universities for indirect costs supporting government-funded research. These require additional guidelines to clarify policy and stop the abuse," he said in announcing the first round of changes in April.

The initial proposed revisions (since published in the May 15 *Federal Register*, page 22618) specifically forbid, among other items, reimbursement for entertainment and alcoholic beverages, housing and personal expenses of university officials, country-club and social-club memberships, and salaries above $120,000 per year.

As NIH director Healy comments, such charges are so obviously remote from research that no one can argue the wisdom of disallowing them. What is surprising is that they have been legal before now.

Most of the abuses that have been revealed in Dingell's hearings are addressed by that first set of proposed OMB revisions, points out Carol Scheman, policy analyst with the Association of American Universities (AAU). Scheman says AAU, which represents major research universities, favors addressing the indirect-cost controversy through changes to existing OMB regulations, as opposed to new laws.

AAU, however, is unhappy with OMB's more recent proposal to cap reimbursement of the administrative parts of indirect costs at 26%. Currently, university administrative overhead rates range from 12 to 45%. Those whose rates now fall under the cap would be reimbursed at the current rate, whereas those with higher rates would get less money.

"This proposal is very inequitable," Scheman says. "It would take a huge chunk out of a very limited number of schools without relieving the paperwork burden. For example, Columbia University would lose $7

Indirect cost rates: a confusion of calculations

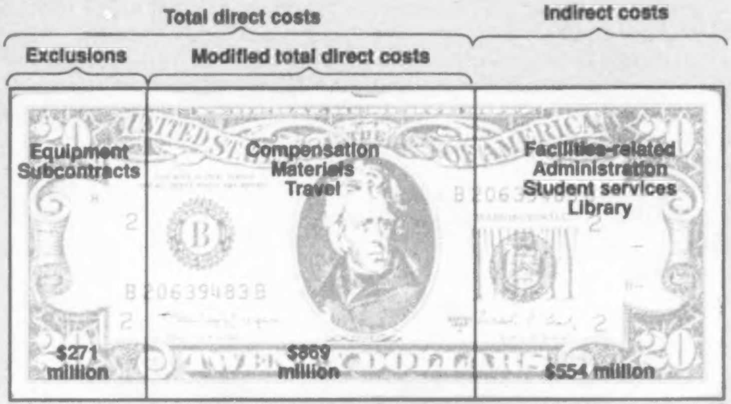
Testifying before Congress in late April, Rensselaer Polytechnic Institute president Roland W. Schmitt said his institution's current indirect cost recovery rate is 59%—about average for research universities. Yet, he later explained, 72% of Rensselaer's research funds are spent on direct costs such as salaries, equipment, and supplies. The other 28% goes to overhead expenses not easily attributed to specific research projects.

Schmitt was not contradicting himself. Rensselaer can spend just 28% out of each dollar on indirect costs and still have an overhead rate of 59%. For in the game of academic cost accounting, calculating an indirect cost rate is not as simple as dividing overhead costs by the total amount of research funds.

Rather, the rate is calculated as the ratio of indirect costs to a subset of direct costs. Office of Management & Budget rules require that certain direct expenses be excluded before the rate is computed. Then once the ratio of overhead to modified direct costs is determined, it is used as the recovery rate in future grant proposals and billings.

For example, Stanford University reports it received nearly $1.7 billion in federal research funds during the 1980s. The university charged $554 million of those monies, about 33%, as indirect overhead costs. The other $1.1 billion was charged directly to individual grants.

Out of those direct costs, about $271 million was spent on equipment and large subcontracts that OMB says must be excluded from the overhead recovery rate calculation. The remaining $869 million is the modified total direct cost. Dividing the indirect cost by the modified total direct cost yields an overhead rate of 64% for Stanford for the decade as a whole.



Stanford's total federal R&D funds, 1980–89 = $1.69 billion
Indirect costs as % of total R&D funds = 33%
Indirect costs as % of total direct costs = 49%
Indirect costs as % of modified total direct costs = 64%

Source: Stanford University

million. It costs more to administer research in New York City."

OMB's administrative cap is almost the opposite of what AAU proposed two years ago in its report, "Indirect Costs Associated with Federal Support of Research on University Campuses: Some Suggestions for Change."

The AAU report proposed setting not a cap but a threshold rate on administrative costs, something like the standard deduction for income taxes. Such a threshold would save money by eliminating paperwork, the report reasoned. Under the scheme, universities that chose to document a claim for a higher administrative indirect cost rate could do so.

But not only OMB is proposing to cap certain indirect administrative costs. Two separate House committees have drafted bills that also would place 26% caps on administrative costs. (Ironically, Dingell, who raised the whole issue in the first place, believes it's too early in the study of the problem to impose legislative solutions.)

The caps are contained in separate bills that reauthorize NIH and the National Science Foundation. The NIH reauthorization bill, as amended by the House Energy & Commerce Subcommittee on Health & the Environment, contains so many controversial provisions in addition to the overhead cap that its fate is dubious.

The NSF reauthorization, however, reported to the House for floor action by the Committee on Science, Space & Technology, stands a chance of passage.

While both bills directly address the administrative portions of indirect costs, they do not place caps on a second controversial category—buildings and facilities. Many in the university community believe it is lack of direct federal support for research infrastructure that has driven private universities in particular to try to squeeze as much money out of indirect costs as they can. The bills, however, do specify that indirect costs paid for depreciation or use allowances may only be used for construction, repair, or renovations of facilities primarily devoted to research.

There will certainly be more changes to come before the dust settles. Although the White House Office of Science & Technology Policy has yet to get into the act, the science committee bill requires OSTP to chime in with a study on which costs can be properly deemed direct and how indirect costs are allocated.

"Everyone would admit there are legitimate costs related to research that can't be identified as direct charges," says John R. Wiesenfeld, Cornell vice president for planning and chairman of ACS's Committee on Chemistry & Public Affairs. "Clearly it's a problem that's got to be solved by government working in cooperation and in harmony with academia." □

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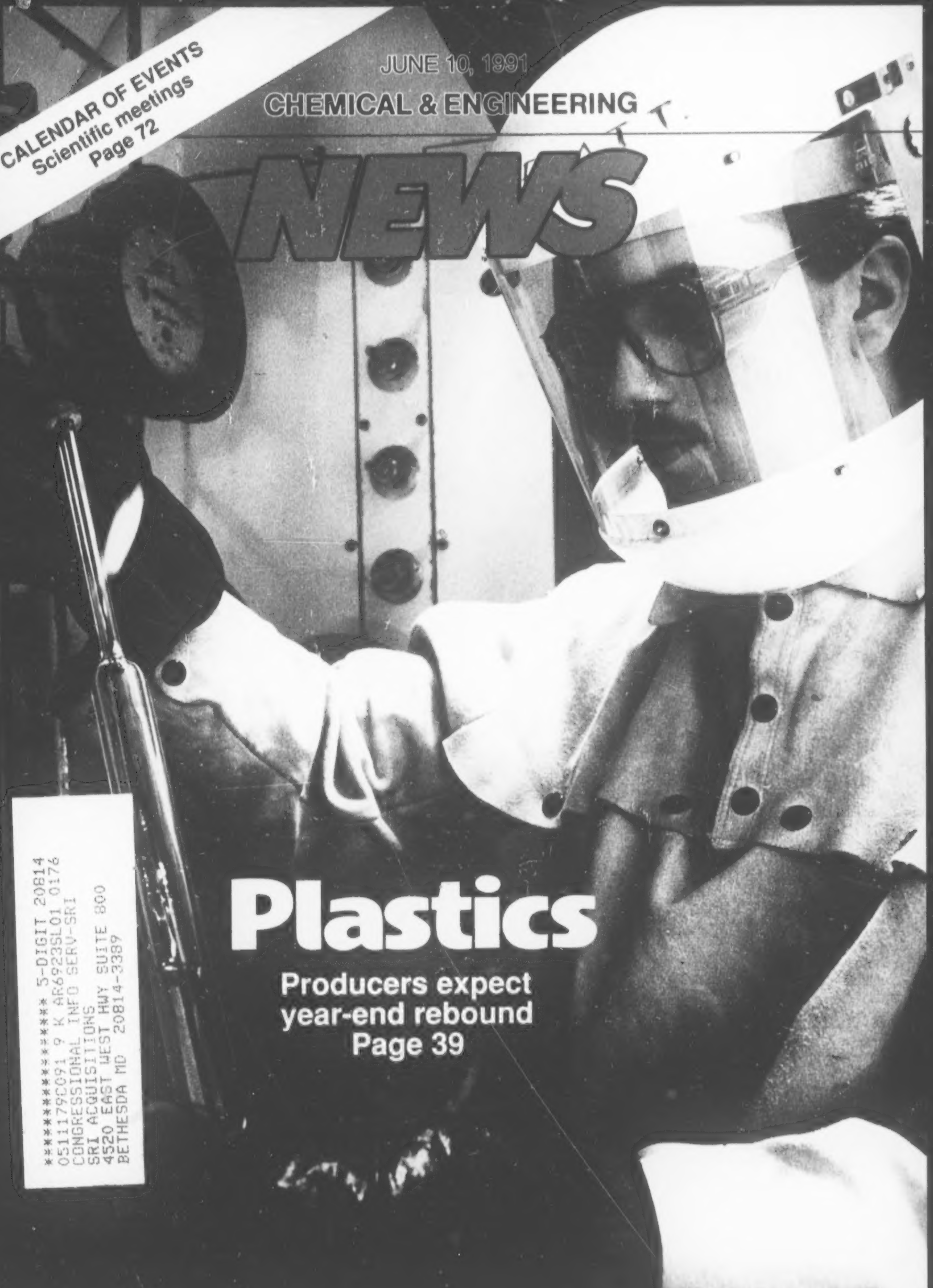

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Volume 69, Number 23
CENEAR 69 (23) 1–90
ISSN 0009-2347

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Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
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Subscription Rates 1991: Printed editions: nonmembers U.S. 1 yr. $95, 2 yr. $171; outside U.S. 1 yr. $131, 2 yr. $243. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $12. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

CHEMICAL SAFETY

Perfluorinated organic compounds

The oxidation by molecular oxygen of a substrate in a supposedly inert perfluorocarbon liquid released considerably more energy than anticipated. Pressure and temperature far exceeded the expected values, leading to a potentially serious incident.

Subsequent conversations with knowledgeable coworkers elsewhere within Dow indicated that perfluorinated organic compounds are more reactive with oxidizers—particularly oxygen gas—than is widely believed. In view of the commonly held belief that such compounds are essentially inert, we strongly encourage anyone considering the use of these compounds in the presence of oxidizers to have appropriate reactive chemical evaluations done first.

We also ask that suppliers of such materials reevaluate their material safety data sheets to heighten users' awareness of the reactivity of perfluorocarbons with oxidizers.

Bob Dawe
Ram Gopal
Przem Pruszynski
Dow Chemical Canada Inc.
Sarnia, Ontario

Priestley Medal Address

I read with pleasure Harry B. Gray's Priestley Medal Address (C&EN, April 15, page 17) and his tribute to his mentors, teaching, research, and luck. It is with a mixture of amazement, disbelief, and nostalgia that I reflect on the differences between the support of science research then and now. Gray's reminiscence that his first grant from the National Science Foundation was actually invited by Oren Williams is remarkable by today's standards. Imagine that! An NSF or National Institutes of Health project director calling you up and saying they'd like to give you some funds for research.

If the report from the American Association for the Advancement of Science is correct and the senior scientists in our country are discouraged, how should their younger peers feel? My experience has probably been similar to many younger (under 40) researchers. This past year alone I have submitted eight different grant applications to private and public funding sources only to be approved for funding, but not funded. As children we learned that close only counts in horseshoes and hand grenades. To be ranked seventeenth on a list of approved grants by one agency, which then funded only 16 grants, was a mega-disappointment. After three years of grant writing, I have received one $10,000 award from an external agency, which was appreciated, but the return per hour spent writing proposals was very low.

Daniel Kleppner presents a fine analysis of the funding squeeze on basic research in "The Mismeasure of Science" (*The Sciences*, May/June 1991, page 18) where he tracks where the governmental research funding priorities lie today. With two thirds of the recent past and present federal R&D expenditures going toward defense projects such as the B-1 bomber, 96 out of 100 of which are grounded; with the B-2 bomber, which will be scuttled; with the Navy A-12 plane, which has been aborted; with a space station project that consumed $1.9 billion last year; with assorted projects of the National Aeronautics & Space Administration, Star Wars, and Antarctic exploration, I have little wonder why basic research dollars are so few. (Perhaps the military would let NSF or NIH sell those planes for spare parts, and then use the funds for basic and medical R&D?) In addition, with a $210 billion annual interest on our national debt and the country in a recession, there will be no significant increase in basic research dollars unless the governmental priorities change dramatically.

Why then do I and many of my peers still persist in this quixotic fashion: underfunded, overstressed, often underpaid, and looking toward a bleak national future? I think Gray is correct in that most of us stay in research and education because we are "doing something that is so much fun." I think scientists still work with the hope that our efforts will push back the frontiers of knowledge, educate, and maybe even help people. (We are also overqualified to sell shoes or auto parts, and too proud to beg on the street.)

The tragedy that lies ahead is that we will not be able to inspire, encourage, or

Booming MTBE Demand Draws Increasing Number of Producers

Starting as an octane booster and developing to clean fuels component, MTBE is industry darling—demand for it is likely to increase 25% by 1995

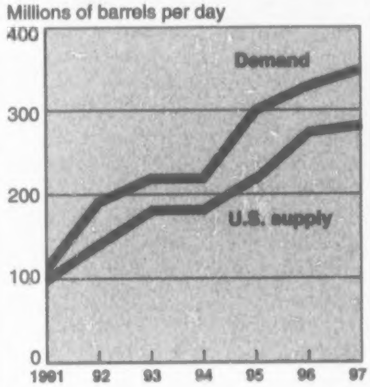
Susan J. Ainsworth, C&EN Houston

Methyl *tert*-butyl ether (MTBE) holds a highly esteemed position in the chemical industry: It has been the fastest growing chemical of the 1980s and it likely will continue to hold that distinction throughout the 1990s. Just how high MTBE's demand growth rate soars will depend on a number of complex factors, but some sources say it could potentially top 25% per year by 1995.

"MTBE is unique in that it basically started as an octane blending component and [now] 10 years later the primary use has started to change to that of a clean air component. I can think of no other chemical that has experienced this unique growth profile," says Bill Ludlow, a vice president at DeWitt & Co., Houston, who spoke at the consulting firm's 1991 Far East Petrochemical & Gasoline Review in Singapore last week.

An increasing number of companies are making the same observation and are finding the market for the octane booster irresistible. Right now, there are no U.S. plants solely dedicated to MTBE. Soon there will be at least five big ones. Tenneco Gas' natural gas liquids/methanol unit claims it will build the first such plant by mid-1992 at LaPorte, Tex. Coastal Chem Inc. plans to complete its unit by spring 1992 in Cheyenne, Wyo. Also sometime next year, Global Octanes' MTBE unit at Deer Park, Tex., is slated for completion. In 1993, Valero Energy plans to finish one at Corpus Christi, Tex., and the newly formed Freedom Group in Philadelphia plans to have an MTBE unit running at Morris, Ill., later that year. These plants alone will add a total of 55,100 barrels per day of MTBE to the 100,000 bbl per day that is current domestic capacity.

MTBE supply, demand to more than double by 1997



Source: Tenneco

The activity seems to be just beginning. More companies are reportedly poised to jump on the production bandwagon, assuming they can secure financing, permits, equipment, and raw materials. For example, DeWitt says it is working with four more companies that are thinking of building grass-roots facilities. Engineering and construction company M. W. Kellogg, which is working under its third MTBE plant contract, says it is also conducting confidential studies with companies still pondering investment in new units for the chemical.

In addition, many more companies are boosting MTBE capacity at existing facilities. These capacity additions, which average about 2000 to 3000 bbl per day, are "slam dunks for refiners," says Ludlow. These moves cost only about $15 million each, so "you can expect that almost every refiner with a fluid cracking catalyst unit will make the move if they have not already." Those small additions alone will add roughly 100,000 bbl per day to domestic capacity through 1993. In addition, new and existing facilities may be able to squeeze out even more product, thanks to a higher yielding technology unveiled just two weeks ago by UOP Inc., a joint venture of Allied-Signal and Union Carbide.

Five firms plan to build MTBE capacity in U.S.

	Site	Daily capacity (barrels per day)	Cost ($ millions)	Completion
Coastal Chem	Cheyenne, Wyo.	4,600	$ 72	Spring 1992
Freedom Group	Morris, Ill.	12,500	300	Late 1993
Global Octanes	Deer Park, Tex.	12,500	200	1992
Tenneco Gas	LaPorte, Tex.	12,500	160	mid-1992
Valero Energy	Corpus Christi, Tex.	13,000	230	mid-1993
TOTAL		55,100		

Sources: Company statements, DeWitt & Co.

Despite the wave of construction, U.S. producers of MTBE will not be able to single-handedly meet soaring demand for MTBE in winter 1992, when the Clean Air Act mandated oxygenate requirement for carbon monoxide nonattainment areas takes effect. According to DeWitt estimates, U.S. production of MTBE will grow from 100,000 bbl per day currently used for octane applications to at least 250,000 bbl per day by the end of 1993, assuming an average operating rate of 78%. But Ludlow estimates U.S. MTBE demand will blossom to at least 327,000 bbl per day as soon as the end of 1992.

In order to satisfy 1992 winter demand, it will be necessary to operate the existing MTBE plants all year and to store product for the peak winter month uses, says Ludlow. A rough estimate is that the U.S. will have to store at least 20 million bbl of MTBE to produce the required amount of oxygenated gasoline for next year. Producers are moving on this and have significant amounts in storage already, he notes.

In addition, it will be necessary to bring in MTBE from other countries' plants, he adds. A number of overseas facilities are going up, undoubtedly with an eye on the U.S. market. For example, National Methanol just awarded a contract to Fluor Daniel to build a 700,000 metric-ton-per-year grass-roots MTBE plant in Al-Jubail, Saudi Arabia. And Mobil Corp. and Chemvest, a Saudi Arabian petrochemical investment firm, expect to complete engineering studies by year's end for one of the largest MTBE plants in the world, which would likely be in Yanbu, Saudi Arabia. Late last year Kellogg began design and construction work on an MTBE-propylene plant for MTBE Malaysia in Kuantan, Malaysia.

The U.S. could successfully import MTBE simply because producers can fetch a good price. "Since late last year, spot MTBE has been selling at higher-than-octane value. This is because in the U.S., both MTBE producers and refiners realized MTBE is really no longer just an octane component; it is a clean air component," says Ludlow.

Accordingly, he notes, the price formula for MTBE and most large contracts have changed from an octane formula. Essentially, producers have incorporated rack gasoline

Regulations continue to spark MTBE demand

Demand for the world's fastest growing petrochemical, methyl *tert*-butyl ether (MTBE) has been largely driven by regulations. In the 1980s, refiners turned to MTBE to replace the octane lost when the U.S. government initiated a lead phasedown for gasoline. And now, MTBE is entering its second growth stage, which will stretch well into the 1990s. MTBE will now also be used as an oxygenated fuel additive needed to reformulate gasolines so that they meet requirements under the Clean Air Act amendments that take effect in 1992, says Bill I. Ludlow, a vice president at DeWitt & Co. (Houston).

The first phase of attack by the Clean Air Act amendments involves 44 areas of the country that have not met the carbon monoxide (CO) emission standards set by the Environmental Protection Agency (EPA). Beginning in November 1992, it will be necessary for these areas to sell gasoline that has at least 2.7% oxygen content during winter months. David E. Gushee at the Library of Congress' Congressional Research Service in Washington, D.C., believes oxygen will be supplied in either one of two forms: ethanol or MTBE. Methanol, *tert*-butyl alcohol, ethyl *tert*-butyl ether, methyl *tert*-amyl ether, other ethers, and mixtures of these will also play roles, he says.

However, this first deadline could change. According to Gushee, the Clean Air Act amendments give EPA the authority to waive for one year (with the possible extention of one additional year) the oxygenate requirement subject to specified findings. "There are two bases on which this waiver can be granted: inadequate domestic supply of or distribution capacity for oxygenated gasoline or oxygenates," he says. "The biggest issue in the phasing in of oxygenated fuel is the meaning of 'inadequate domestic supply.' "

It's likely the refining industry will have to wait until EPA's final rule-making deadline of Nov. 15 to find whether the agency will grant a waiver, Gushee conjectures. Although EPA reportedly completed a proposal on this issue late last month, it "is being closely guarded" at the Office of Management & Budget, says Gushee. "I'll make a bet that EPA is leaning toward defining domestic supply in an expansive way," including product that "could be shipped from somewhere else in the world." That would mean the affected areas would have to be in compliance by winter 1992. He reasons that EPA will feel pressure to more rigidly uphold the Clean Air Act mandates simply because it is the agency responsible for cleaning up the air and environment. Even if EPA takes a stand on this issue now, as oil companies have asked it to for planning purposes, "a cloud of uncertainty will hang over this issue until November due to its controversial nature. And that uncertainty will have an effect on private-sector planning."

Although the oxygenate initiative is starting with gasoline in CO nonattainment areas, explains Gushee, it will soon spread to ozone nonattainment areas, which represent larger parts of the gasoline market. Beginning in January 1995, the nine worst ozone nonattainment areas must sell reformulated gasoline containing at least 2% oxygen content year round. Six of these areas also happen to be CO nonattainment areas, and so will already be selling oxygenate-rich gasoline to meet the 1992 deadline, he adds. Besides 2% oxygen, the new ozone law requires that reformulated gasoline have a maximum benzene content of 1% and a maximum aromatics content of 25%. "Just as hotly contested as the domestic supply issue is the question of how reformulated gasoline will ultimately be defined by EPA," Gushee notes. The refining sector is anxious to know which oxygenates will be suitable and how much it will cost to comply, he says.

"Since the U.S. currently consumes over 7 million barrels per day of gasoline and is the largest gasoline market in the world, [these two mandates will create demand for] large amounts of MTBE equivalents," says DeWitt's Ludlow. He points out if moderate ozone areas decide to "opt in" and use oxygenated fuel voluntarily, demand will climb even higher. But, he says, it is conceivable that "politicians in a compliance area might, for publicity's sake, make an issue of opting in to get this new 'clean gasoline.' "

prices—those charged by refiners at their terminals and traditionally higher than wholesale prices—into the formula. The result: The price of MTBE has risen roughly 10 to 12 cents per gal. "Even though there were some objections by the oil companies to this new formula, they generally accepted it," says Ludlow. "They realized that paying a higher price for MTBE was more acceptable to them than being forced to use alternative fuels."

Demand for MTBE will continue to rise sharply into the mid-1990s. By 1995, as the year-round ozone requirements of the Clean Air Act amendments go into effect, Ludlow predicts U.S. demand will reach 388,000 bbl per day in the winter and 164,000 bbl per day from March through October. That estimate could get even larger if some areas decide voluntarily to buy the cleaner oxygenated fuel, he notes.

These demand scenarios are great news for the construction industry. "To meet U.S. demand over the next five years or so, there will be a need for at least another dozen plants," says a Kellogg spokesman. These plants, some of which might be built outside the U.S. with export capabilities, would need to produce on the order of 12,000 bbl per day, about the capacity of those now being built. "So we're talking about several-billion-dollar investments that will be made just to meet U.S. demand. And on top of that, demand in Europe is growing, too."

Increasing MTBE imports and the seasonality built into the 1992 carbon monoxide requirements alone will create opportunities for storage tank manufacturers and terminal operators, notes Paul Fields of Houston-based Pace Consultants. He notes that although MTBE is stable and presents no storage problems, "our analysis indicates that [storage] is somewhat impractical, because of the large amount of tankage required." But, he adds, "this will happen to some extent, however, presenting an opportunity for tank manufacturers and terminal operators."

Obviously recognizing this niche early on, Texas Eastern Products Pipeline Co. (TEPPCO) recently unveiled plans to store and transport via pipeline increasing quantities of the chemical (C&EN, May 20, page 6). Says TEPPCO vice president David L. Langley: "Pipeline transfer, which is one of the most efficient means of MTBE transport, will play an important role as regional demand begins to exceed a region's supply, and the availability of efficient and cost-effective logistics becomes the limiting factor in its usage."

Another, more critical limiting factor in the supply of MTBE may be feedstock availability. For example, early last month the National Petroleum Refiners Association (NPRA) released an MTBE plant survey that revealed unexpectedly low capacity utilization rates averaging 63.6% over the three-year period 1988–90. NPRA says it received responses from all 22 captive MTBE plants in the U.S. The primary factor resulting in low utilization was feedstock availability.

"The biggest concern right now is supply of methanol," a key raw material for the production of MTBE, says Ludlow. There is some reluctance on the part of methanol producers to commit to new plants. Ten years ago, many plants were built to supply the expected demand for methanol as a gasoline additive, but that demand did not materialize, he explains. "The same guys that had to go to the board 12 years ago and ask for the money for those failed plants don't want to have to go back again." But that hesitance is subsiding and a lot of plants are starting to come on-line, according to Roy Sugimoto, a consultant with expertise in engines and fuels at DeWitt. That's because the price of methanol has

UOP unveils high-yield oxygenates process

Just as demand for oxygenates is booming, UOP Inc. has unveiled a new, high-performance process for producing oxygenates methyl *tert*-butyl ether (MTBE), ethyl *tert*-butyl ether (ETBE), and methyl *tert*-amyl ether (TAME) from isobutylenes and isoamylenes. The new process, called Ethermax, is designed to produce higher yields of C_4 and C_5 ethers with lower investment and operating costs than other etherification technologies. Says Steve T. Bakas of UOP's MTBE marketing group: "We expect significant interest in the Ethermax process for MTBE/TAME production because of the Clean Air Act in the U.S. and a growing emphasis worldwide in the use of oxygenates in gasoline."

The Ethermax process is the result of the joint efforts of Germany's Hüls A.G. and Koch Engineering Co., Wichita, Kan., as well as UOP, a joint venture of Allied-Signal and Union Carbide based in Des Plaines, Ill. The new process combines the engineering design and operating experience of UOP and Hüls with Koch's proprietary reaction with distillation (RWD) technology.

The RWD technology makes use of Katamax structured tower packing, Koch's dual-function, mass transfer/catalyst contacting equipment. Katamax packing provides efficient mass and heat transfer between vapor, liquids, and solid catalyst, accomplishing effective fractionation and olefin reaction in a single zone. This technology achieves higher ether production by overcoming the equilibrium limitations of single-stage, fixed-bed processes. Compared with conventional single-stage technology, an Ethermax unit can increase isobutylene conversion from 96 to 97% by weight to more than 99% and can increase isoamylene conversion from 70% to 91%.

The process involves reduced equipment investment, in most cases, because reaction and distillation are combined in one vessel, compared with the need for two reactors with conventional technology. It also has a reduced catalyst requirement, compared with conventional technology, says UOP.

Several companies are "actively looking at this process now, but it is too early in the game for any of them to have finished their evaluations," says Bakas. One of those companies is Tenneco, which has begun construction of its 12,500 bbl-per-day MTBE plant at LaPorte, Tex. UOP estimates Tenneco could produce an additional 300 bbl per day at its new plant should it decide to incorporate the new technology. The Ethermax process will be available for all future MTBE, ETBE, and TAME units and for retrofits of existing units, says UOP.

cycled and is now up to more than 60 cents per gal, he says.

Sources are more mixed about whether supply of isobutylene, the other key raw material in production of MTBE, will be much of a problem. This really relates back to the supply of butane, which is isomerized and dehydrogenated in some processes to make isobutylene. Sugimoto says his research indicates there's probably enough butane readily available to satisfy demand.

It's not surprising that the companies that have committed to new MTBE units have feedstock and transportation or storage advantages. Says Kenneth W. Reese, vice chairman of Tenneco Inc., parent company of Tenneco Gas: "We're entering a market that is going to grow quickly, and we're entering with several competitive advantages that will allow us to be out in front of the wave, not caught up in it."

Tenneco Natural Gas Liquids produces isobutane at its LaPorte complex, site of the proposed facility; it makes methanol at the company's nearby plant in Pasadena, Tex. Plus, the company says it will use its LaPorte distribution facilities for rail, truck, and barge shipments of MTBE as well as the company's product pipeline network to transport MTBE to terminals and refineries in the Houston area.

For its part, Coastal Chem is touting its $72 million, 4600 bbl-per-day Cheyenne unit as "the first fully integrated MTBE complex in the world." The facility will go up adjacent to its existing agricultural products plant. Coastal's plant will rely on butanes coming from Wyoming gas-processing plants. It will have the advantage of not having to get its methanol from an outside source like most producers; it is building a 26 million gal-per-year methanol unit on site. Both natural gas and butane feedstocks will be delivered by parent Coastal Corp.'s Colorado Interstate Gas Co.

Another factor on Coastal's side: the location of the new unit. MTBE is already used extensively in the Rocky Mountain region to achieve mandatory oxygen content requirements during winter months in order to reduce carbon monoxide levels, according to Mike Ray, executive vice president and chief operating officer of Coastal Chem.

Global Octanes' Deer Park, Tex., facility will have the advantage of being a neighbor to the Intercontinental Terminals facility in Houston. "That means that [Global Octane] can buy isobutane right off the pipeline, eliminating the need for an isomerization unit, which saves it quite a bit of money," notes Ludlow. And that location is a big plus, he adds, considering "that much of the cost of producing MTBE lies in the tankage and storage of not only the raw materials but also of the finished product."

Meanwhile, Valero has access to large quantities of butane, which it will convert into MTBE at its 13,000 bbl-per-day, $230 million plant. It will get 100% of the butane needed for the project from its own operations—Valero Natural Gas Partners and Valero's refinery.

Although feedstock sources may be close at hand for these companies, the speed with which the number of MTBE plants now under construction or in engineering can be completed depends on several conditions such as securing the proper financing as costs rise, getting the necessary permits in a timely fashion, and finding a place on an engineering and construction firm's schedule. "The lead times [for plant construction] are certainly longer than they were even two years ago," adds Ludlow.

Prospective MTBE producers are also apprehensive about whether EPA will opt to waive the Clean Air Act oxygenate requirement for one or two years, softening 1992 demand for MTBE. "A delay would put companies that have invested in plants at a competitive disadvantage. So, some companies have a wait-and-see attitude," says one source.

Still, some observers say it's hard to envision a domestic oversupply of MTBE right now. "I cannot foresee MTBE being long in supply until the latter half of this decade," says Charles L. McSpadden, vice president of market analysis at Bonner & Moore Associates, Houston. "If we were to use only domestic MTBE, we would have to double or triple capacity in the next five years, and that's very tough to do" given the constraints on building a plant quickly (such as financing, rising costs, equipment availability). "MTBE [supply] will be tight throughout most of this decade, as far as I can see."

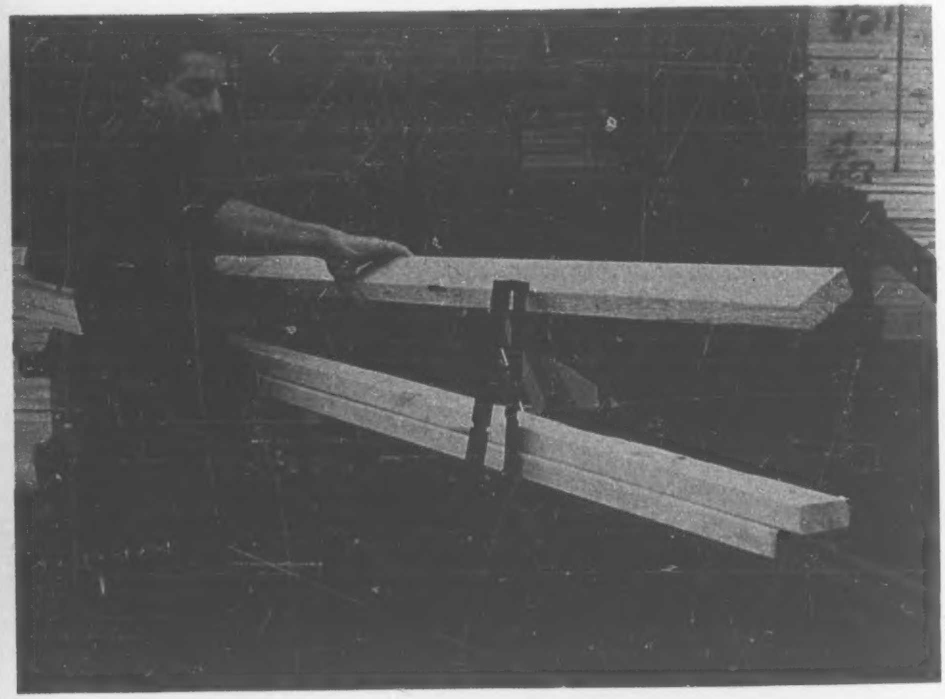
There's always going to be demand for MTBE, argues DeWitt's Sugimoto, because it is useful as a high-octane blendstock. When the government takes aromatics out of gasoline as part of the 1995 reformulated gasoline mandate, MTBE will help offset the resultant octane loss, he says.

Also, MTBE is favored over alcohols as both an octane booster and an oxygenate. That's because direct blending of alcohols presents problems, including high blending vapor pressures, water affinity, and associated phase separation. Also, methanol is incompatible with some fuel system components and poorly accepted by consumers, according to McSpadden. The more favorable outlook for fuel ethers is based on several attributes: little or no water solubility problems and general acceptance of ether-gasoline blends, he adds.

In addition, MTBE blends like a hydrocarbon and requires no extraordinary handling procedures by the refiners, adds Ludlow. "And MTBE is a fungible product," which means it is interchangeable and is accepted by all refiners. This makes the trading of gasolines in the U.S. system workable, Ludlow says. And MTBE has an edge over other ethers such as ethyl *tert*-butyl ether and methyl *tert*-amyl ether, in that MTBE is currently more readily available, Sugimoto says.

Ironically, although new and rigorous government regulations have been making life miserable for producers of a host of chemicals, new regulations continue to be the source of prosperity for MTBE producers. The icing on the cake is that MTBE producers can also get a lot of public relations mileage out of their participation in a business with positive environmental implications. Tenneco vice chairman Reese sums it up well: "When our financial and environmental goals complement each other, as they do here, it's a powerful combination. We make a return on our investment, and society lives in a protected environment." □

Plastics Producers Look For Turnaround by Year's End



Twin U-shaped auto carrier racks for transporting extra-long items are molded of tough nylon resin

Mobay photo

Bruce F. Greek, C&EN Houston

Demand and production of plastics slipped into the down phase of a business cycle early this year, but they're likely to turn back up as early as the third quarter. Currently industry sources believe that demand, output, and pricing are at the year's nadir.

The downturn is expected to be enough, however, to cause 1991's total output of plastics to fall slightly from last year's. Most producers estimate a decline of less than 1%, or about 500 million lb, from the 60 billion lb or more of total production estimated for last year.

Estimates of total plastics output are all that's available because the official reports on plastics production compiled by the accounting firm Ernst & Young for the Commitee on Resin Statistics of the Society of the Plastics Industry (SPI) and statistics gathered by the U.S. International Trade Commission omit some of the numerous small-volume plastics. Including these, guesses by industry sources of total 1990 output are in the 60 billion to 65 billion lb range.

If demand strengthens beyond current expectations, output of a few resins could turn up slightly this year. Higher demand at a time when inventories are low could spur producers to operate plants at production levels higher than are now forecast for the third and fourth quarters.

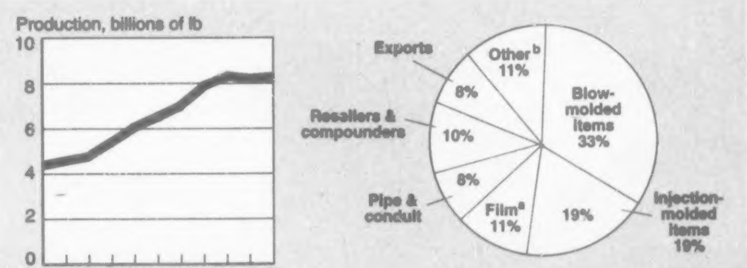
Over the longer term, the majority of plastics will continue their traditional growth in demand and production. Most sources forecast this growth rate will be lower, however, than in the 1980s.

Several environmental actions are beginning to reduce growth from the levels previously forecast for the 1990s and beyond. For example, paper, glass, and metals are now substituting for plastics in some uses. And recycling of plastics and outright bans on certain types of plastics are depressing growth.

However, the decline in plastics production this year is generating less concern among producers than is the slump in selling prices. All large-volume resins currently are selling below their posted prices. And selling prices continued to fall this spring, especially in export markets. The difference between contract and actual selling price varies among these resins but ranges from 10 to 25%.

Many small-volume plastic products—for example, engineering and specialty resins—are faring slightly better in maintaining sales volume and prices. Epoxy and acrylonitrile-butadiene-styrene (ABS) resins are experiencing sales and price declines similar to the polyolefins. The truly specialty resins, those having very small volumes, are posting gains owing to the development of special niches. Similarly, sales of some blends and alloys of plastics are showing gains, while those of other types are declining.

HDPE: blow-molded items keep growth high



1990 sales & captive use = 8.7 billion lb

a Less than 0.012 inch. b Sheet (over 0.012 inch), wire and cable, rotomolding, and all other.
Source: Committee on Resin Statistics of the Society of the Plastics Industry

U.S. demand for high-density polyethylene (HDPE) is expected to exceed 10 billion lb in 1995, up from over 8 billion lb forecast for this year, which is 30% of global demand of about 27 billion lb. Widespread plant construction will allow capacity to grow and keep pace with or exceed demand.

All major uses of HDPE except exports will grow substantially, says Dennis L. Rohlfing, resins marketing manager of Phillips 66. Blow molding and injection molding have the largest share of uses and are expected to grow 3 to 4% annually over the next five years. Film and sheet uses will grow 9 to 10%, Rohlfing forecasts.

Blow molding, consuming about a third of U.S. HDPE, will have much of its demand growth concentrated in food bottles and auto gas tanks. Containers for products other than milk also contribute to blow molding use. If resin supply continues to be ample and prices rise only slightly, increased conversion of half-gallon size milk bottles to HDPE could stimulate growth. Consumption in motor oil bottles rose from almost nothing in 1985 to 300 million lb in 1989. This use could decline because increased amounts of recycled resin are being used and because of a shift toward bulk delivery of lubricating oils to "quick-change" shops.

Injection molding will require about 1.8 billion lb of HDPE in 1995. Pails for packaging applications, thin-walled food containers, and a large number of consumer and industrial uses will lead growth in this use, says Rohlfing.

Most recycling of HDPE will be blow-molded and injection-molded items. By the year 2000, half of some fabricated products, such as milk and motor oil bottles, will be recycled, he forecasts.

Sales managers are cutting contract prices for large-volume plastics in an attempt to bring them closer to actual prices. Price reductions in March and April were larger than those for preliminary prices for May. The inventory liquidation by consumers that began in late 1990 has further reduced sales. Most industry sources agree that further lowering of prices may occur, but they doubt that it will be as large as the earlier drop.

Because inventories are low and the recession likely has bottomed out, there is some optimism for the rest of 1991. Inventories of the size and extent of the past's may be over. Both plastics producers and fabricators now can't afford the cost of maintaining large inventories, especially of lower volume grades. When demand increased significantly, as it did after previous slumps, inventories then proved worth more than their maintenance cost in avoiding lost sales, point out several industry sources.

Lower selling prices have caused profit margins for plastics to slip dramatically since late last year. Earnings for many of the producers have dropped more than prices and margins, reflecting the difficulty of reducing monomer and other manufacturing costs as rapidly as sales dollar volume declines. Cost-cutting programs are helping somewhat. These programs are forecast to increase profit margins by a large amount later in 1991 and into 1992 (when demand growth is expected to resume).

The drop in selling prices and margins has its source in more than a slowdown in demand. Completion of additional capacity, increasing competition with other nonplastic materials, and competition among polymers also have caused the price cuts designed to gain market share and capture new markets. Competition among polymers has rapidly increased the number of different grades of plastics that are available. Newly commercialized polymers also are being pushed into existing markets. Although margins that provide investment for new polymers and their commercialization are narrowing, these numerous developments continue.

Lower selling prices and plant operating rates for most plastics, especially thermoplastics, now have profit margins perilously near breakeven. Cash costs (for monomers and manufacturing but not for depreciation) temporarily may be higher than selling prices in some cases, as producers seek to sell additional pounds of plastics. Export sale prices and returns after paying freight and insurance have been particularly hard hit by competition from areas needing hard currency.

Export sales have long been a way of bolstering production when domestic markets are weak. Following declines that began more than a year ago, two important sectors of the domestic market for plastics—building and construction and transportation equipment—are still weak. Building and construction accounts for more than half the use of polyvinyl chloride (the largest volume thermoplastic) in pipe, siding, and wire and cable covering, according to data compiled by Ernst & Young. Unless construction (particularly housing) increases faster than during the first quarter of this year, PVC consumption will be lower than last year.

Despite efforts to increase exports, plant operating rates are significantly down from peak levels. Except for high-density polyethylene (HDPE), the rates range from 70 to 80% of nameplate capacity. The HDPE operating rate at the end of the first quarter was above 80%. These rates generally are expected to decline during this year, as new capacity comes on stream and plant process improvements are completed. For most of the large-volume thermoplastics, planned capacity expansions are relatively small. Capacities to make HDPE and polypropylene are exceptions. Although other planned expansions are small, they will be added at a time when demand growth will be yet smaller.

However, digesting the expansions that have been or are being built in the two-year period 1990–91 is difficult at this time. For example, nameplate capacity to make HDPE will increase 3.2 billion lb, or 40%, between the beginning of 1990 and the beginning of 1992 to reach more than 11.1 billion lb, according to data compiled by Pace Consultants. The capacities for the low-density polyethylenes (LDPE) will grow considerably less during the same time, about 1.3 billion lb or 10%, says Hugh S. Pylant, a senior consultant at the firm. Capacity for both polypropylene and PVC will be increased about 1.6 billion lb, or 18% and 15%, respectively. Only polystyrene capacity will grow marginally, with an increase of about 250 million lb, or about 4%, to bring the total to more than 6.7 billion lb by the beginning of 1992.

Reflecting demand, production of these large-volume thermoplastics (except for HDPE and polystyrene) increased by large amounts in 1990. Because of Phillips' loss of a major HDPE plant in an explosion and fire in Deer Park, Tex., late in 1989, output of this resin has been limited by a lack of capacity. Had demand growth held up this year, production of the thermoplastics may have increased by substantial amounts to cover at least part of the new capacity. Because of the slump in demand, however, output of many thermoplastics is expected to be down this year. Therefore, the average growth over 1990 and 1991 will be well below capacity expansions during that same time.

Except for exports, all of the major uses of ABS and other styrenic polymers (such as styrene-acrylonitrile) fell early this year. Exports were up about 25%, to more than 60 million lb, or nearly 20% of sales and captive use. The jump in exports shows that they are crucial in maintaining output for these mature plastic resins.

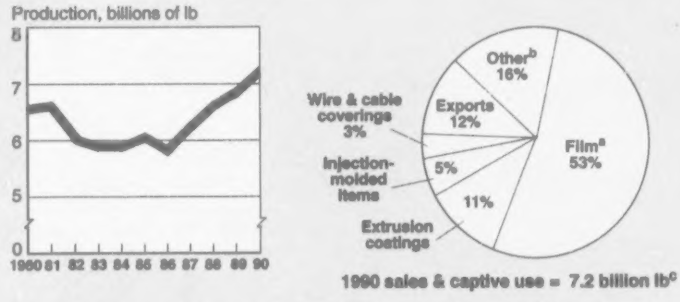
Exports also have been important to other thermoplastics, enabling some to buck the trend of lower production and sales. Exports of both nylon and thermoplastic polyester resins have increased substantially this year, after posting gains in 1990. Nylon exports amount to more than 15% of sales and captive use that includes imported material. Thermoplastic polyester exports will account for about 30% of sales and captive use this year, compared with about 20% last year. The polyester export growth this year offset declines in domestic uses and provided gains in total sales and production over the first quarter of last year.

The nylon demand situation differs from that of polyester. So far this year, domestic consumption of nylon has been holding up well, de-

LDPE: aging polymer still growing

Output of low-density polyethylene (LDPE) is growing again after declining for several years as a result of the partial shift toward linear low-density polyethylene (LLDPE). Limited by capacity restraints, U.S. demand will continue to increase, averaging more than 2% annually over the next five years. Other polyethylenes now are seldom substituted for the low-density material. Special properties available from the highly branched structure of LDPE are unobtainable in other polyethylenes.

The economics of operating aging plants, use of LDPE to avoid paying for more costly resins, and the profitability of investment returns from available prices will determine how long the rising demand can be supplied. If manufacturing costs of this resin go up, the lower value markets will be forced to pay more or find alternative materials, says David L. DeMocker, LDPE product manager at Dow Chemical. Sales of the resin as a uniquely designed product will then increase.



a Less than 0.012 inch. b Sheet (over 0.012 inch), blow molding, pipe and conduit, other extruded products, adhesives and sealants, resellers and compounders, and all other. c Including imports. **Sources:** Committee on Resin Statistics of the Society of the Plastics Industry, SRI International, Union Carbide, C&EN estimates

As developing markets in the Pacific Rim and Latin America grow, export demand for LDPE will remain strong, says DeMocker. Less sophisticated equipment and available technical service in those countries will cause an even greater need for its ease of processing.

Because of higher returns, more of the high-pressure process technology (by which LDPE is made) is being converted to make ethylene copolymers, points out DeMocker. The copolymers are more difficult to produce and require slower production rates, effectively reducing capacity. Therefore, he says, the future supply-demand relationship will become tight for this plastic despite incremental capacity expansions.

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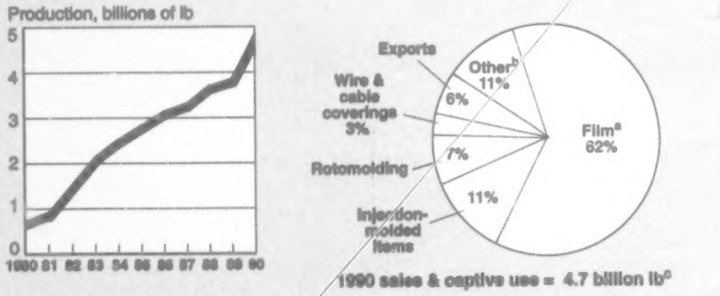
LLDPE: film use propels high growth rates

In the past decade, demand for linear low-density polyethylene (LLDPE) jumped from less than 750 million lb to more than 4.7 billion lb, an average annual growth rate of about 20%. Such growth will not be sustained during the rest of the 1990s, but growth nevertheless will be substantial.

In most areas of the world, LLDPE growth will significantly outpace other competing large-volume plastics, such as conventional low-density polyethylene and high-density polyethylene. New capacity is under construction at numerous locations. Often this is "swing" capacity that can be used to make either LLDPE or HDPE.

Assuming that growth for low-density polyethylenes is 2.5% annually for the U.S., Canada, Western Europe, and Japan, and is 5% annually for the rest of the world, global demand can be expected to rise from about 41 billion lb in 1990 to about 57 billion lb in 2000, says Ronald J. Cottle, business manager for polyolefins at Union Carbide. If, as has been occurring, the LLDPE gets most of the increased demand, the average growth rate would be more than 15% annually; if it gets half, the rate would be more than 7% annually, Cottle points out.

Film dominates use of LLDPE. It also is the fastest growing use. However, the surge in 1990 reflects a film inventory reduction in 1989, Cottle says. Exports remain the other fast-growing use. Exports doubled in 1989 and increased from 174 million lb to 255 million lb in 1990.



1990 sales & captive use = 4.7 billion lb^c

a Less than 0.012 inch. b Sheet (over 0.012 inch), blow molded items, pipe and conduit, resellers and compounders, and all other. c Including imports. Sources: Committee on Resin Statistics of the Society of the Plastics Industry, SRI International, Union Carbide, C&EN estimates

spite declines in sales of various kinds of durable goods containing parts made of nylon (such as automobiles and appliances). If demand for nylon continues at current levels and then picks up (if the recession ends this fall as expected), then sales and captive use of nylon resins could tack another small gain to the more than 580 million lb of record sales in 1990.

Nylon 66 (salt of adipic acid and hexamethylenediamine) and nylon 6 (caprolactam) comprise about 90% of nylon resins consumption. The several other nylons, fabricated mostly for specialty uses in the same general use categories as nylon 66 and nylon 6, account for the remainder.

Various injection-molded items accounted for more than half of 1990 nylon consumption, according to SPI data. A diverse range of automotive and truck parts alone required 30% of consumption in 1990. About three quarters were nylon 66. The remainder was mostly nylon 6, with small quantities of nylon 11 (11-aminoundeconoic acid) and nylon 12 (laurolactam) used in fuel system parts. Most of the remaining uses in molded items include electrical parts (especially connectors), small parts for appliances and machinery of many kinds, household hardware and furniture, and parts for other consumer items. Nylon development work goes on continually for these molded and other uses, yielding forecasts for demand to grow an average of more than 5% annually.

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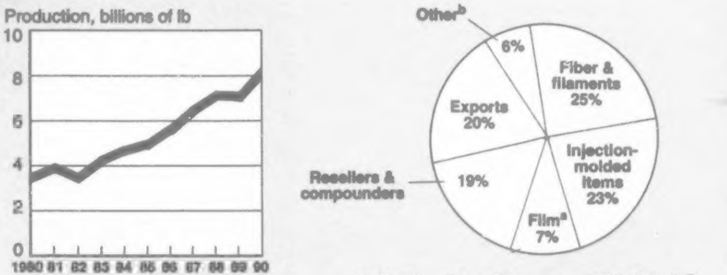
Polypropylene: recycling, declining exports could slow growth

U.S. demand for polypropylene in 1991 is expected to decline slightly. Growth in demand probably will resume next year, but at a slower pace than between 1980 and 1990 when growth averaged 8% annually. Average growth in the first half of the 1990s will be 5% annually, or 2 to 2.5 times that of the gross national product. By 1995, U.S. domestic demand is expected to exceed 8.5 billion lb.

In 1990, U.S. demand for polypropylene was more than 6.6 billion lb. Exports of over 1.6 billion lb brought total demand to some 8.2 billion lb for another record year. The larger markets are in fibers and filaments, injection-molded items, and film.

The development of new grades, to render the resin more competitive with other materials and open new markets, will boost growth in demand for polypropylene, says David A. Durand, plastics market research manager for Shell Chemical. Recycled material would be the most important deterrent to growth, as the whole effort on plastics recycling expands beyond high-density polyethylene, thermoplastic polyester, and polystyrene to include large quantities of polypropylene.

However, exports also could decline and slow production growth of polypropylene. In the next five years, more than 11 billion lb of capacity will be built outside the U.S., Durand estimates. Much of the additional capacity will be in the Pacific Rim region, currently an area of high imports of polypropylene from the U.S. He forecasts that exports will decline at the rate of 9% annually through 1995.



a Less than 0.010 inch. b Blow molding, sheet (more than 0.010 inch), extrusion coatings, and all other. c Including imports. Source: Committee on Resin Statistics of the Society of the Plastics Industry

Extrusion fabrication uses take another 25% of nylon resins. Film, often laminated with other plastic resin film, goes largely to many packaging uses that take advantage of properties such as low gas transmission and easy thermoforming. At above 5% annually, growth in films is expected to be high, especially for coextrusions and biaxially oriented forms.

Other extrusions include nontextile monofilaments used in bristles, fishing line, grass trimmer line, and woven support forms for waistbands of trousers. Extruded tubing of nylons is used to carry air and other fluids or as sheathing for steel cable. Nylon resins may be added over other plastic covering of wire and cable to provide better abrasion resistance. Nylons other than 66 and 6 often are used in extrusions. Use of these other extrusions is expected to grow at rates averaging about 5% annually, slightly less than that for film.

Thermoplastic polyester is the other largest thermoplastic having production and consumption data compiled by SPI. After this resin became commercially available in the mid-1970s, production grew unabated until 1989, when output slipped 1.3% because increased prices made it

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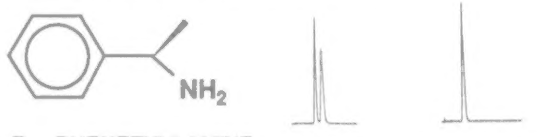

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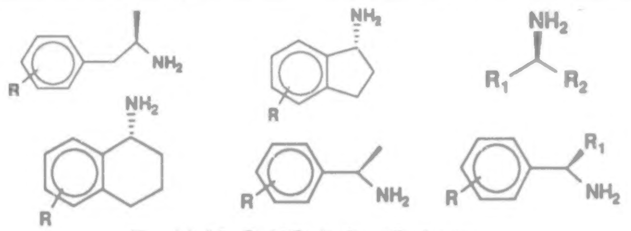

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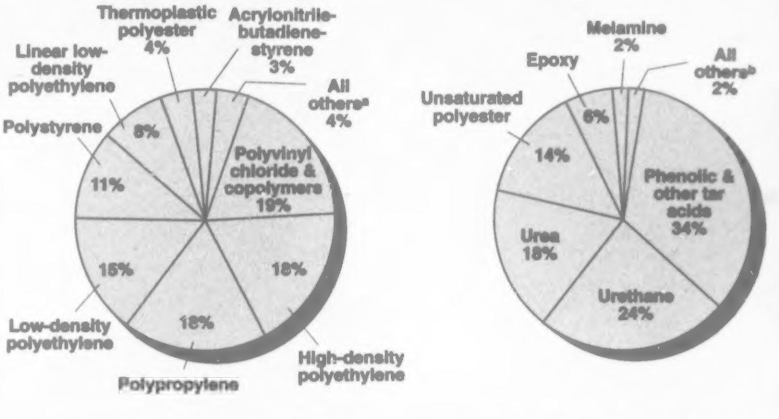
less competitive with other packaging materials such as aluminum and glass. During the 1980s, however, output zoomed from 500 million lb to more than 1.6 billion lb for an average growth rate of 14% annually.

Bottle grades of thermoplastic polyester accounted for 70% of domestic consumption in 1990. Film and engineering resin uses took the remainder. Soft drink bottles, especially the 2-L size, now continue to grow, but at a slower rate than in the mid-1980s. The major growth now is mostly in containers for foods, liquor, wine, toiletries, and other consumer products.

Thermoplastics production nears 50 billion lb . . . **. . . while that of thermosets is less than 15% as large**



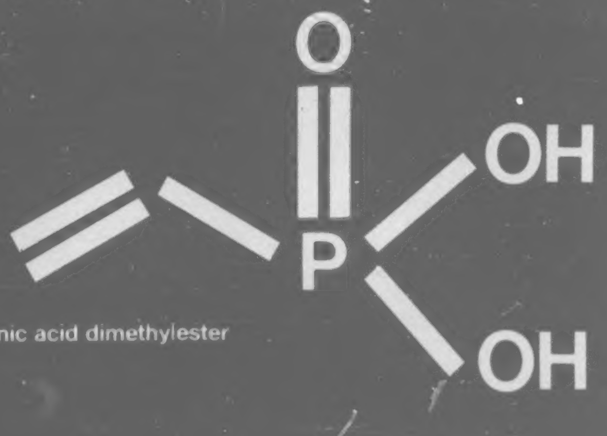
1990 production = 46.8 billion lb

1990 production = 8.6 billion lb

a Production of less than 1 billion lb; nylon, polyvinyl acetate, styrene-acrylonitrile, other styrenic plastics, other vinyls, and other thermoplastics. b Includes other amino resins, furfural resins, glyoxal-formaldehyde resins, and silicone. **Sources:** Committee on Resin Statistics of the Society of the Plastics Industry, U.S. International Trade Commission, C&EN estimates

Polyester resins have a strong competitor in glass for smaller size bottles, such as half-liter (16 oz) bottles for soft drinks. The beer bottle/can size of 12 oz provides even greater competition, so a major move by polyester resins into these containers has been stymied. Because of concern over whether consumers will separate plastic, glass, and aluminum containers, recycling of polyester used in containers is uncertain. Other concerns are the recycled uses for polyester, which replace virgin material.

About a fifth of the thermoplastic polyester resins consumed in the U.S. is fabricated into biaxially oriented films. The largest use is in various kinds of photographic films in-



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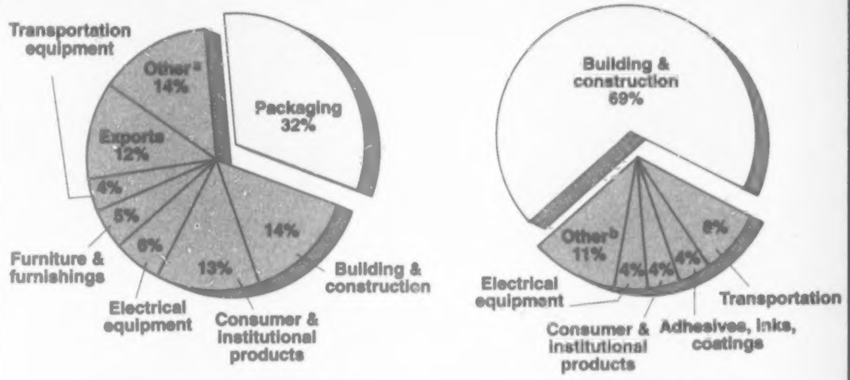
Packaging accounts for nearly third of thermoplastics use . . . **. . . and building, construction over two thirds of thermosets**



1989 sales & captive use = 46.3 billion lb

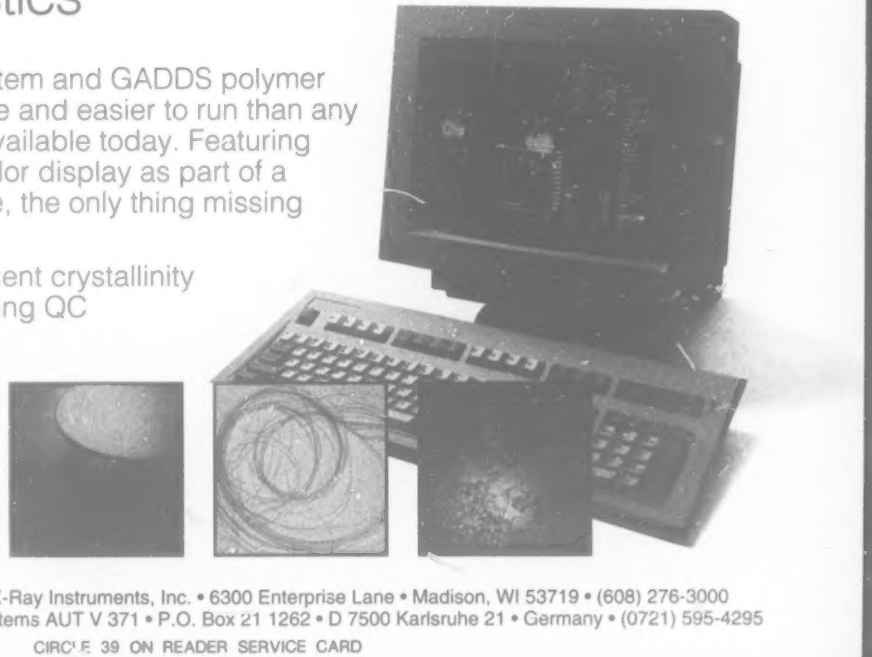
1989 sales & captive use = 6.3 billion lb

Note: Selected large-volume thermoplastics and thermosets; 1990 data not available yet. a Includes adhesives, inks, coatings; industrial equipment and machinery; volumes sold to resellers and compounders; and not classifiable elsewhere. b Includes furniture and furnishings, packaging, industrial equipment and machinery, exports, volumes sold to resellers and compounders, and not classifiable elsewhere. **Source:** Committee on Resin Statistics of the Society of the Plastics Industry

cluding x-ray film. But because this use is growing slowly, it soon could be surpassed by electronic media tapes. Videotape growth has slowed because its base has become so large, but the physical volume growth is forecast to continue.

A large group of other applications round out film uses. None of the miscellaneous uses are growing as fast as electronic media applications, but the miscellaneous uses do exceed photographic film uses. Packaging uses rank first among the miscellaneous group, with most going to food packaging. Other uses include numerous electrical applications (because of insulating and strength properties required), graphics and reproduction, various kinds of pressure-sensitive tapes, and metallized films. As a group, this use of polyester resins is forecast to grow 3 to 5% annually.

The remaining thermoplastic polyester resins are used as engineering resins, including the butylene and ethylene forms. The fastest growing segment of engineering resins is blends and alloys with other plastics, most of which are ultimately fabricated into parts for automobiles such as bumpers, other body parts, and numerous under-the-hood parts. Other uses are parts for appliances, electronic and electrical devices, industrial equipment, and machinery. Because of a surge in automotive applications (current-



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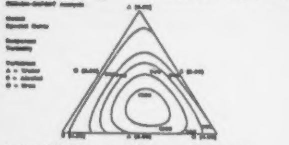

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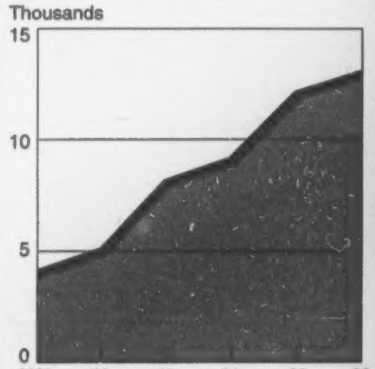
ly dampened by the slump in auto production), growth in use as an engineering resin will be 5 to 10% annually for the next few years.

Among the large-volume thermoset resins for which data are available, epoxy and urea/melamine resins also are having another down year. Both of these groups of resins had relatively poorer sales growth in 1990 than the major thermoplastics and this year the outlook for the two calls for a decline as well. These resins have large uses in the building and construction and the transportation industries, and total demand is heavily influenced by these applications.

Exports are important to demand for epoxy resins, taking about 20% of the total in 1990. During the first quarter of this year, exports of epoxies increased slightly and were the only bright spot among the various uses.

More than half of U.S. consumption of epoxy resins is accounted for by coatings. Earlier this year, use in coatings dropped 5 to 10% as auto production declined. Because of the continued weakness in sales of autos, demand for epoxy resins for coatings will be flat this year, say officials at Dow Plastics, a business group of Dow Chemical. Demand in other markets, however, will mean a modest growth for these resins through 1992. Overall, this translates into a projected 3 to 4% growth in the use of epoxy resins during the next two years, says Thayne Hansen,

Number of polymer grades tripled in the 1980s



Source: Chem Systems

market group manager for Dow's coatings group.

Uses of epoxy resins in various kinds of reinforced composites and laminates are next in size, at more than 20% of total U.S. consumption. In recent years, demand for composites has grown between 10 and 20% annually, according to the Suppliers of Advanced Composite Materials Association. The growth rate is expected to slow, however, as the base gets larger.

Laminates are used in printed circuit boards for electronics equipment. Other epoxy resins are used as molding compounds for semiconductor encapsulation. The current downturn in demand for epoxy resins in electronics applications is expected to gradually turn around, says Kenneth Hawthorne, market manager for electron-grade thermoset resins at Dow Plastics.

Future growth rates will not be in the double-digit range. Between now and 1995, Hawthorne puts the growth for epoxy resins in laminates at between 3 and 5% a year and for encapsulant resins at 5 to 6% a year for an average of 4 to 5%. Among the reasons Hawthorne cited for the slower growth are further miniaturization of electronic equipment and some saturation of markets. Thus, he doubts there will be a need for additional capacity to make these epoxy resins.

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mats, prior to the addition of asphalt to make roofing shingles, increased rapidly as this kind of shingle replaced others. However, this type of roofing shingle has captured about as much of the market as it can.

Some uses, such as in paper and textile coatings, face competition from other resins. Urea resins impart wet strength to paper but are being replaced by other materials. Textile use also declines as these resins are replaced by materials that do not have the potential toxicity of formaldehyde. Growth prospects are low because of the maturity of most of these uses.

Melamine resins cost more than urea resins, but they have better resistance to moisture and temperature extremes and have greater hardness when cured. Because of these properties, their largest use is in coatings, generally in complex systems from which high performance is expected. For example, they may be combined with epoxy resins in primers for automotive use and with acrylic resins for auto top coats. In a similar fashion, melamine resins go into coating systems for appliances, metal containers, machinery, and coil coatings.

Of other uses of melamine resins, decorative and other laminates rank second, followed by paper treating and coating. Both high- and low-

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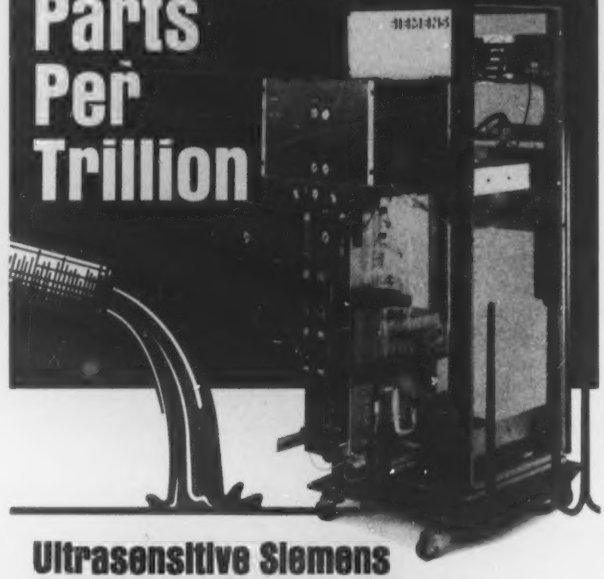

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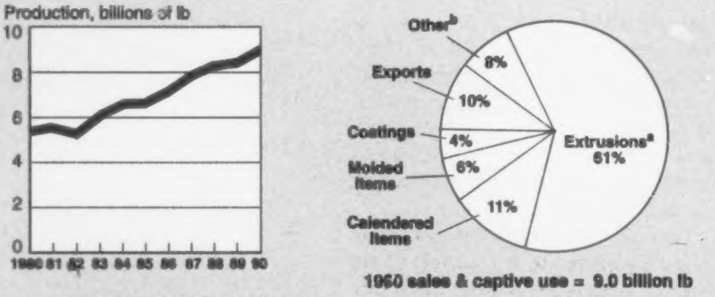
PVC: extruded products support growing demand

Production of polyvinyl chloride (PVC) has grown steadily since 1982, but the recession is causing slippage this year. If they persist, the output declines early this year could be too much to overcome a decline in 1991 despite improved demand this fall. Early estimates place 1991 output down 3%, or about 300 million lb, from 1990 output of 9.1 billion lb.

But production is expected to grow after this year, as demand recovers in the U.S. In contrast, global demand will slow in 1991 and is forecast to grow later at a compound annual rate of 3.7%, to bring the total to 58 billion lb in the year 2000, says Richard H. Roman, manager of marketing and business research in B. F. Goodrich's Geon Vinyl Division.

Over the past several years, global demand for PVC has increased 4 to 5% annually, bringing it to about 40 billion lb in 1990. This growth is about 2 billion lb per year, roughly equivalent to the capacity of four new PVC plants and two world-scale vinyl chloride plants, Roman points out. Plant utilization in 1990 stood at a relatively high 93% of effective capacity. (Effective capacity accounts for actual operating conditions that reduce output from nameplate or design capacity.)

Exports contribute strongly to demand, accounting for about 10% of the total. Roman forecasts that exports from North America will continue to be strong during the 1990s because of a cost advantage. Capacity will continue to be short in the Asia/Pacific region, causing the region to be a net importer of PVC throughout the decade.



1990 sales & captive use = 9.0 billion lb

a Includes pipe and tubing, siding and accessories, wire and cable covering, and film and sheet. b Paste processes (except coatings), resellers and compounders, and all other. Source: Committee on Resin Statistics of the Society of the Plastics Industry

pressure laminates (related to curing conditions) are widely used in housing and commercial buildings as countertops, panels, and furniture parts. Demand for these laminates depends on housing construction and remodeling and ancillary activities such as furniture purchases. Demand this year is forecast as being soft again.

The other uses of melamine resins also have low growth prospects for this year. Paper-treating uses depend on demand for higher quality papers, a use that slowed as a result of the recession. Competition from other resins such as styrene-butadiene and polyvinyl acetate latices reduces growth prospects. Other uses in molding compounds, plywood resins (often blended with urea resins), and many smaller uses will grow at low rates and not have significant impact on total demand.

A large number of other plastics are produced and consumed globally. Data on their production and consumption vary in availability and reliability. Some of these plastics have been commercially available for many years, and others are just entering commerce. Some of these polymers were developed for

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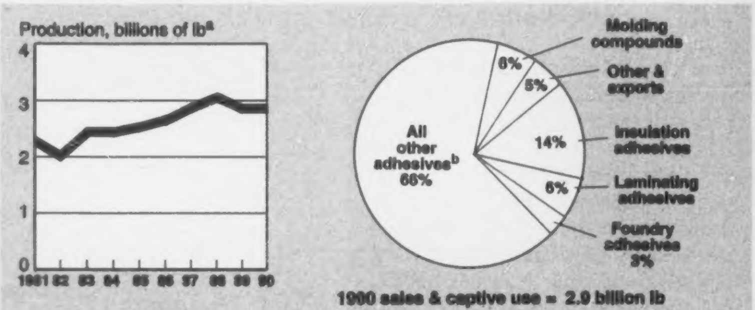
CIRCLE 11 ON READER SERVICE CARD

Phenolics: mature products, lacklaster outlook



1990 sales & captive use = 2.9 billion lb

a Gross weight reported beginning in 1981; earlier data not comparable. b For disclosure reasons, plywood adhesives are not broken out; in 1989, plywood adhesives accounted for 51% of total sales and captive use. Source: Committee on Resin Statistics of the Society of the Plastics Industry

Demand for phenolic and related tar acid resins could drop 10% in 1991, following four years of nearly flat demand. Phenolic resins, which include some of the oldest known plastics, are very mature products. Hence, future production growth is expected to be modest beginning next year.

Phenolic resin production and sales data are reported by the Society of the Plastics Industry on a gross basis that includes the weight of solvents, fillers, and colorants. Actual resin content varies widely—from 40 to 80% solids content, depending on use.

Plywood adhesives typically take more than half of U.S. consumption. As a result of disclosure problems, data on consumption in plywood are no longer available. Similarly, data on use in making fibrous and granulated wood board have not been available since 1987. Before that year, this use was reported as accounting for about 10% of U.S. consumption.

These adhesives and others used in insulation materials (more than 10% of consumption) eventually end up in buildings of various kinds. Construction (more than 80% of the end market for phenolic resins) began to slow in 1989 and demand for phenolic resins turned down. A recovery may begin in 1991, but the resumption of annual growth will only come in 1992, says Kenneth H. Brockschmidt, product manager at Georgia-Pacific.

All other uses of phenolic resins total 10 to 15% of consumption. Because of their small size, these other uses won't significantly affect demand even though their growth rates surpass that of the gross national product.

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MAKING THINGS WORK

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specific uses and then found to have many other uses, spurring growth in demand. Others, also developed for specific uses, were found to have one or more deficiencies (high cost being prominent) that have held down growth or were replaced by other plastics or materials.

Polyurethanes are one of the largest in this group. Almost 3.3 billion lb of materials, including isocyanates, polyethers, polyesters, blowing agents, catalysts, fillers, and other additives, were consumed in 1989 (latest year data were available) in urethanes, according to SPI data. More than half of urethane output in 1989 was flexible foam, 26% rigid foam, 5.4% coatings, 6% adhesives and sealants, and 9.5% elastomers.

The urethane use pattern is diverse. More than 17% of urethanes went into construction uses in 1989, almost 23% into transportation, 19% into furniture, and 10% into carpets, with appliances, packaging, bedding, and miscellaneous uses accounting for the remainder.

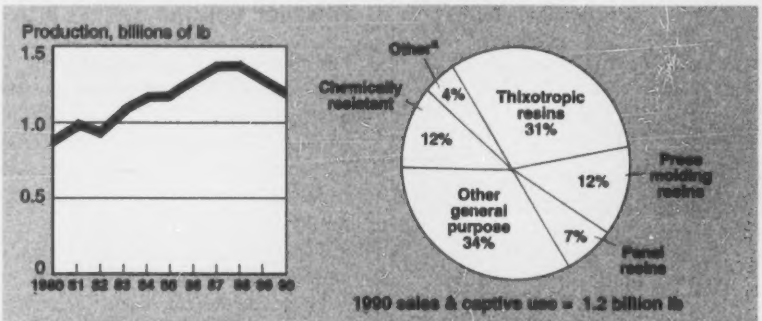
Production, sales, and use of the urethane materials grew until 1989, when a downturn occurred for some and minimal growth for others. The outlook for this year is for flat de-

Unsaturated polyester: output continues to fall

Slowing demand for many kinds of durable goods continues to affect unsaturated polyester resins. Output this year could fall more than 10%, following a 7% drop in 1990. A pickup next year is expected, but a return to production of more than 1.4 billion lb (as in 1988) is not likely.

A large share of this group of resins is used in products considered to be luxury items or descretionary spending items. About 80% of the resins are used with reinforcements (such as glass fiber) in building components such as bathroom fixtures, underground tanks, boats and accessories, and automotive parts. The remainder goes into nonreinforced products.

These resins are made largely of an acid component, a glycol, and styrene. Phthalic and maleic anhydrides dominate the acid components and propylene glycol dominates the glycol group. Styrene and a few other unsaturated hydrocarbons make up the rest of the materials used.



a Exports and flame-retardant resins.
Source: Committee on Resin Statistics of the Society of the Plastics Industry

Products made of unsaturated polyesters have varied with the ebb and flow of interpolymer competition. For example, use in microwave cookware boomed in the mid-1980s, but since has been largely replaced by thermoplastics. More recently, auto engine parts are being made of these resins.

Other engine parts could be made from these compounds because they withstand temperatures now being encountered under automobile hoods and allow fast cycling times for injection molding, says John S. Holroyde, director of sales for thermoset composite molding compounds at American Cyanamid. Holroyde forecasts that growth in use of such compounds will be 10 to 15% annually.

mand since most end uses are in housing and transportation—markets that are having off years.

Excluding naturally occurring resins, synthetic plastics have been coming to market for 125 years. Cellulose nitrate is often cited as the first commercial plastic developed, with liquid crystal polymers and polymethylpentene among the most recent entrants in the marketplace.

Alloys and blends of plastics long ago became recognized as routes to properties not so economically obtainable in single resins. A few of these mixtures were known before World War II, but most have been developed since 1950, says Joel H. Levy, senior market research analyst at Allied-Signal's Engineered Plastics Group. Nevertheless, this segment of the plastics industry is not mature; almost daily new alloys and blends come to market and new producers enter the marketplace.

Alloys differ from blends in the molecular forces involved, says Levy. Alloys have a tighter, denser molecular structure. They also have some significantly improved properties—a synergistic effect—in comparison to the individual compo-

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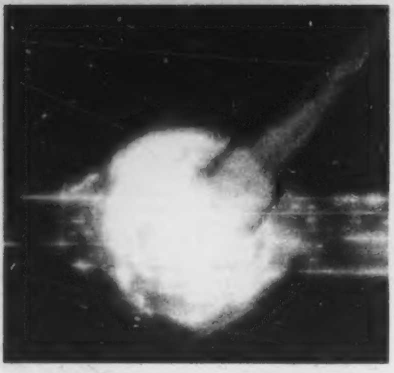

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Smaller volume resins found in most use areas

For more than a century, chemists in laboratories worldwide have developed a large number of polymers. A relatively few have been commercial successes, but efforts continue unabated to find additional commercially important plastics.

Following are some examples of smaller volume plastics that have met modest commercial success, according to the Society of the Plastics Industry.

Acetals (made from formaldehyde) used in parts for automobiles, consumer products, and machinery.

Acrylics (made from acrylic and methacrylic esters) used in auto parts and glazing.

Alkyds (made from organic esters and aromatics) used in automotive and electrical parts, and coatings.

Cellulosics (made from cellulose and organic acids) used in packaging, parts for automobiles, and consumer products.

Coumarone-indene resins (made from coumarone, indene) used in processing aids, extenders, and plasticizers.

Fluoropolymers (made from halogenated olefins, olefins) used in parts for electrical/electronic equipment, tubing, and coatings.

Nitrile resins (made from acrylonitrile, esters, butadiene, styrene) used in packaging.

Petroleum resins (made from mixed unsaturated monomers recovered from petroleum processing streams) used in adhesives, coatings, inks, and processing aids.

Polyamide-imide resins (made from trimellitic anhydride, aromatic diamines) used in parts for aerospace, automobiles, and machinery.

Polycarbonates (made from bisphenol A, diphenyl carbonate, phosgene) used in parts for appliances, consumer goods, and electrical equipment.

Polyimides (made from dianhydrides, diamines, diisocyanates) used in parts for autos and electronic equipment.

Polyphenylene oxide resins (made from xylenol) used in parts for appliances, automobiles, business machines, and electrical/electronic equipment.

Polyphenylene sulfide resins (made from *p*-dichlorobenzene, sodium sulfide) used in parts for autos, electrical/electronic equipment.

Sulfone resins (made from bisphenol A, substituted sulfones, potassium hydroxide) used in parts for autos, and electrical/electronic equipment.

nents. Properties of blends generally are the average of those of the individual components.

Alloys are relatively newer, says Levy. A surge in patents attests to the importance plastics producers give to obtaining a proprietary position in supplying these materials. One recent development in technology for making alloys—"compatibilizers"—is used to promote greater chemical bonding and reactive processing during compounding.

Levy cites three types of alloys and blends expected to grow significantly in use through 1995. Nylon-based alloys and blends with polyolefins, elastomers, and other materials will grow from 66 million lb in 1990 to 91 million lb in 1995, for a compound annual growth rate of 6.6%. Polycarbonate alloys with polybutylterephthalate, ABS, and other materials will grow from 135 million lb in 1990 to 196 million lb in 1995, for a rate of 7.7% annually. Various polyester alloys also will grow from 41 million lb in 1990 to 70 million lb in 1995, for a rate of 11% annually.

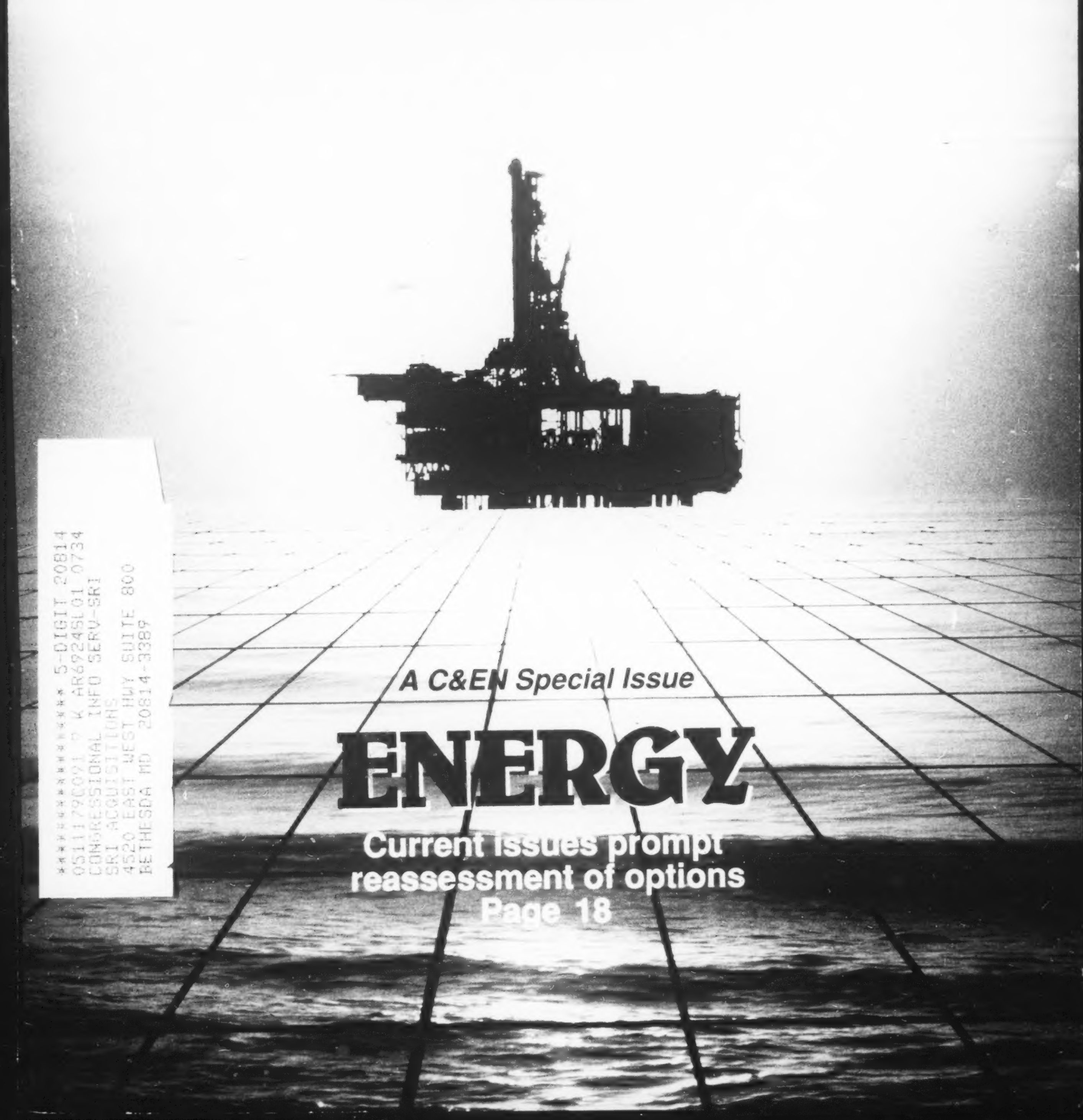
Methods for achieving success in the alloys/blends segment are similar to those for the whole plastics industry. A proprietary system of compatibilizer, polymerization, additives, and fabrication are technical requirements, points out Levy. Marketing requirements are clear targets for end uses and strong end user support. Where possible, economic requirements are captive resin supply and large-volume markets. ◻

PRELIMINARY PROGRAM
4th Chemical Congress of North America
and 202nd ACS national meeting,
New York City Page 47

JUNE 17, 1991

CHEMICAL & ENGINEERING

NEWS



A C&EN Special Issue

ENERGY

Current issues prompt reassessment of options
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Volume 69, Number 24
CENEAR 69 (24) 1–88
ISSN 0009-2347

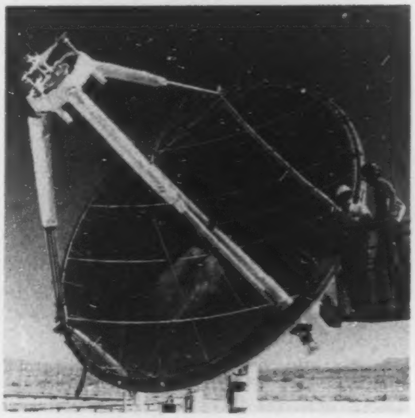
CHEMICAL & ENGINEERING NEWS

JUNE 17, 1991

News of the Week

- **East European chemical output plunges as nations restructure for shift to market economy, but prospects are bright in long term for certain nations and chemical sectors.** Page 4
- **DuPont is giving $225,000 over three years to Howard University to set a up polymer science program.** Page 5
- **CMA begins $6 million national advertising campaign to improve public's image of chemical industry.** Page 6
- **House rejects attempts to delete funding for space station and supercollider as it begins working on appropriations bills for fiscal 1992.** Page 6
- **With $510,000 award to University of Wisconsin, Eau Claire, Research Corp. launches new program aimed at upgrading selected chemistry and physics departments.** Page 7

Cover: Photo by Pictor/Uniphoto Inc.



ENERGY

Attention is again focused on energy policy and technology options as politicians and the public grapple with environmental and political issues. Page 18

Energy Policy

Policymakers must wrestle with the realities of world politics, the need to make environmentally sound decisions, and the difficulties of accommodating the U.S.'s energy-use patterns as they forge an energy strategy for the nation. **Page 20**

Coal

Department of Energy's clean-coal program, which aims to give coal a better image and find environmentally acceptable ways to use it, is key to future utility of this abundant natural resource. **Page 32**

Nuclear

Smaller, standardized nuclear electric power plants under development are designed for incremental generating capacity, simpler licensing, advanced reactor safety. **Page 36**

Solar

Solar generation of electric power has received renewed interest with the sharp fall in costs in the past 20 years for both photovoltaic and solar thermal processes, the two major ways of converting the Sun's energy directly to electricity. **Page 41**

Preliminary Program

4th Chemical Congress of North America and 202nd ACS national meeting in August in New York City offers variety of symposia; listing and highlights of technical sessions, and full general program are included. **Page 47**

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Published by
AMERICAN CHEMICAL SOCIETY
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Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Calcium carbonate

This is an interesting historical footnote about the story on calcium carbonate (C&EN, April 29, page 9). In late 1945 or early 1946, I was operating a fluid bed pilot plant for lime burning at New England Lime Co. in North Adams, Mass. At that time New England Lime was making precipitated calcium carbonate from their very high quality lime (made from a stone that was almost marble) and carbonating it with scrubbed combustion gases from the rotary lime kilns.

The product was filtered, dried, bagged, and sold for use in, among other things, cigarette paper and toothpaste. Later, about 1947, Pfizer bought the company. This may have been Pfizer's first entry into the business, but they may have had other production facilities. I doubt that there is anyone still active in Pfizer that was an employee at the time.

Cigarette paper is hardly a growth market, and this may account for its not being mentioned in the C&EN article.

James V. Thompson
ACS Emeritus
Lafayette, Calif.

Adding iron to oceans

I noted, with interest, the recent debate over the merits of fertilizing southern seas with iron to reduce atmospheric carbon dioxide. Sophisticated arguments have been advanced on the kinetics and practicality of the approach (C&EN, Feb. 4, page 29), but comments on the potential impact of iron addition on the community structure have been surprisingly absent.

The low solubility of iron (III) in many environments makes it a precious resource. Competitive advantage can be gained by organisms able to make special complexing agents called siderochromes that solubilize and tie up available iron. Organisms able to recognize and transport these iron complexes into the cell come to dominate the local community. At least one paper [Murphy, T. P., Lean, D. R. S., Nalewajko, C. *Science*, **192** (4242), 900 (1976)] has appeared showing that this phenomenon explains species succession in freshwater algal blooms. It seems likely that similar control occurs in marine systems.

Although it is not surprising that the indiscriminant addition of available iron to an Antarctic marine algal community should cause a rush of growth and activity, alteration of the overall community structure over time could lead to unpredictable ultimate effects. Iron is not just another nutrient present or absent in adequate concentration; it has been identified in the past as one of nature's most active battlegrounds and a key to determining winners and losers in mixed populations.

Thomas R. Jack
Manager, Applied Sciences
Nova Husky Research Corp.
Calgary, Alberta, Canada

Higher level of integrity

I gather from the content of your editorial on the David Baltimore/Margot O'Toole issue (C&EN, April 8, page 3) that you once held those who were called scientists to a higher level of integrity than the public at large.

My own observation after a lifetime of experience is that they are no more veracious than parsons, popes, or presidents. Only open discussion and competition serve as a brake on less than scrupulous scientists.

Charles V. Berger
Western Springs, Ill.

Hooray for Margot O'Toole and Rep. John Dingell! Truth will out! The system works! We all benefit when arrogant crooks are exposed, regardless of who they are and where they are.

From the number of scientists who supported David Baltimore in his impossible position, it would appear that Dingell and his group still have work to do.

Your editorial on humility is good common sense, understood by many who are scientifically illiterate. Too bad this simple truth has escaped Baltimore and his following.

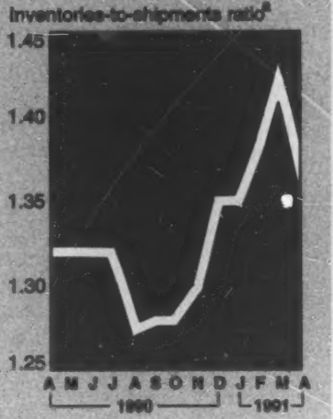
Thomas T. Noland
New Canaan, Conn.

Safety of nuclear power

I feel compelled to respond to the letter of Nancy Adin (C&EN, April 22, page 59). She questions the safety of nuclear power plants on the basis of "how safe is safe." This question should be applied equally to all forms of generating electricity—not just to nuclear. We cannot have a guarantee of absolute safety of nuclear plants. However, the safety of nuclear plants over the 35 years of their existence exceeds the safety of any alternative source of electricity.

Continued on page 87

Inventories/shipments



a Seasonally adjusted.

As a result of increased demand, the shipments-to-inventories ratio for chemicals and allied products fell back to a more normal level in April, according to seasonally adjusted data from the Commerce Department. The government figures show that shipments of chemicals in April rose 5.4% from the previous month after a 3.9% decline in March. On a year-to-year basis, shipments of chemicals and allied products were up 3.0% in April, following an annual decline of 1.2% in March. Inventories of chemicals in April were essentially flat, falling just 0.2% from March, which had been up 1.0% from February. On an annual basis, stocks were up 5.5% in April from the same month a year earlier. In March, inventories had increased 6.3% from March 1990. The result was that the shipments-to-inventories ratio fell to 1.36 in April from a high of 1.43 in March and 1.38 in February. However, the ratio is higher than it had been in April 1990 when it was 1.32.

Amoco, Allied plan fiber pact

Amoco Fabrics & Fibers and Allied Fibers, a division of Allied-Signal, are completing negotiations to form a joint venture to manufacture and market solution-dyed nylon (SDN) for the commercial and residential carpet markets. The companies say that use of SDN yarns, which already account for about 15% of the commercial carpet market, is expected to double in volume by 1995 and triple by the end of the decade when the yarns likely will represent about 40% of the commercial segment. Under the proposed agreement, Amoco will make the yarns at its Bainbridge, Ga., filament yarns plant and Allied will supply the resin as well as market the SDN yarns. Amoco Fibers & Fabrics is a unit of Amoco Chemical.

Du Pont, ConAgra in polylactides venture

A joint venture between Du Pont and ConAgra is developing and planning to market polylactides—polymers made from lactic acid—which have shown biodegradability in laboratory tests. The joint venture, Ecological Chemical Products Co., will develop the polylactide materials from such products as cheese whey and corn. The venture uses proprietary technology to convert these raw materials to high-purity lactic acids, derivatives, and polymers. Commercial quantities of the new polymer material are expected in late 1994. Targeted industries may include paper, printing, packaging, and specialty products.

Enzon to acquire Genex

Enzon, the South Plainfield, N.J.-based biotechnology company, has reached a definitive agreement to acquire Genex, the troubled Gaithersburg, Md.-headquartered protein engineering firm, in a stock swap. Genex has been searching for capital, but has been unsuccessful as a stand-alone company. Reed R. Prior, president and chief executive officer of Genex, says, "This arrangement exemplifies a growing trend whereby cash-poor biotech companies with strong technologies are being acquired by stronger companies looking for complementary technologies and capabilities." Enzon says the acquisition will enable it to expand its product pipeline and strengthen and broaden its technological foundation. The company has agreed, subject to certain limitations, to provide for Genex's interim working capital requirements. The merger is subject to approval by Genex stockholders and is expected to be concluded in September.

Add Exxon to the MTBE list

Exxon is joining the rapidly growing group of companies that are planning units to make methyl *tert*-butyl ether (C&EN, June 10, page 13). Exxon will build a 7000 barrel-per-day unit to produce the gasoline oxygenating agent at its Baton Rouge, La., refinery. The project will take 14 to 18 months to complete, with groundbreaking about six months into this schedule. Cost of the project was not disclosed. Jacobs Engineering will provide engineering and construction services.

RWE-DEA completes acquisition of Vista

The Federal Trade Commission didn't raise any last minute objections and so Hamburg-based RWE-DEA acquired more than 85% of Vista's outstanding shares on June 7 (C&EN, June 10, page 7). Based on the 10.8 million shares it received, RWE-DEA has paid $594 million to acquire its new subsidiary. RWE-DEA will acquire shares not purchased through the tender offer in a subsequent merger at $55 a share. Armin Schram, chairman of RWE-DEA, says the combined companies "can now devote our energies to the business at hand: becoming a more powerful presence in the global chemicals marketplace. We will do so by jointly strengthening our existing marketing efforts while simultaneously expanding into new markets such as the Far East." He also says Vista's corporate headquarters will remain in Houston and that no layoffs or plant closings are planned as a result of the acquisition.

Deltech starts up polystyrene unit in Ohio

Deltech Polymers has started production of prime crystal polystyrene at a newly acquired facility in Troy, Ohio. The unit is rated at an annual capacity of 145 million lb. Deltech bought the 10-year-old plant from Goodsen Polymers in April and has now brought it back on stream a year after it was shut down. No financial details on the startup or cost of the

Coal

In the national energy picture, the Department of Energy's clean-coal program is key to future utility of coal

Joseph Haggin, C&EN Chicago

Coal probably has more "players" than any other energy game. The mining industry, the electric power industry, environmentalists, national and state governments, regional associations, numerous state universities and national laboratories, the major energy companies, and many local jurisdictions all have much at stake in the future performance of coal as a fuel.

Coal is abundant, relatively cheap, and widely distributed. It also is a polluter and has a very bad image. Providing coal with an acceptable image and finding ways to use it within environmental limits is the task of the U.S. Department of Energy's clean-coal program. Most of the players mentioned also have coal development programs, but the clean-coal program is the key to the future utility of coal in the national energy picture.

DOE's general attack in the clean-coal program was outlined recently by Robert H. Gentile, assistant secretary for fossil energy, at an international conference in London. He notes that coal remains a true measure of Earth's collective energy strength. As a part of a "new world order," Gentile calls for a new technological order that will, among other things, permit the use of Earth's most abundant energy source.

The point seems well taken since, as Gentile notes, Earth's population draws nearly a third of its energy needs form coal. Coal generates 44% of the world's electricity and is used in the production of 75% of the world's steel.

Emerging nations of the world use about 30% of the global energy produced, and their consumption is expected to triple in the next 30 years. The imminent consolidation of European markets is another factor in increasing energy competition. EC-92 may be good for Europe, but it will stress the global energy and economic picture still further.

Gentile does not believe that concern over the environment can be used as a valid excuse to limit economic growth, and, consequently, to limit energy use. Neither can it be used as an excuse to deny developing countries the opportunity to improve their living standards. Technology can be developed to accomplish all these things, but it will take time, investment, and the good offices of international associations. Predictably, Gentile believes that the energy strategy of the Bush Administration is sensible because it is based on citizen involvement rather than government intervention and because "we cannot tax ourselves into a better world, but we can innovate."

The clean-coal program has passed several milestones since its inception in 1986. Several demonstration plants recently have been started up, and ground has been broken for others. Gentile foresees the production of motor fuels from coal. The cost of doing this, he says, has been reduced to about $36 per barrel with the prospect of further reductions to about $30 per bbl. Not everyone agrees with that estimate, but it does indicate that technical progress in coal combustion and conversion is being made. And the clean-coal program is a key element in that progress.

The clean-coal program is a joint government-industry cofunded development effort. Its goal is to provide the U.S. with advanced, efficient, and environmentally acceptable coal-consuming technologies. The program began the first of five phases in 1986. Phase I concentrated on new and retrofit applications to increase the use of coal as an energy option. Phase II started the following year and was focused on demonstrating new technologies that can decrease the production of acid rain from coal combustion. Phase III started in 1989 and is dedicated to reducing emissions of sulfur oxides and nitrogen oxides from existing facilities. Phase IV is just getting started (it began in February), and Phase V will begin in March of 1992.

The first three phases in the clean-coal program contained 38 projects, but in December 1990 three of them were canceled—ostensibly for technical reasons but with unfavorable economics playing a decisive role. The remaining 35 projects are still under way, and their completion will permit the sponsors to market the technology that results from the work.

Coal is abundant but has major barriers affecting its use. These are generally acknowledged to be the effects on air quality, the contributions to acid rain formation from the intrinsic sulfur, the contributions to suspected global warming, and the often highly localized pollution from particulate emissions. Coal also figures in the national energy security debate and in the drive to increase industrial competitiveness.

Despite its bad image as an air polluter, coal-burning industries have already spent more than $250 billion to control emissions since 1970. Most of this has been spent by the U.S. electric power industry. As a result, SO_x emissions have dropped dramatically, although much of the drop is also attributed to the use of lower sulfur coals. A number of particularly troublesome plants have also been taken off stream.

Compliance with the newest SO_x and NO_x regulations will cost the electric power industry about $4 billion to $5 billion annually until the end of the century. Eventually SO_x levels will be capped at the levels of the year 2000, which will be about half the 1980 levels. Permissible NO_x levels in 2000 will be those from the best available devices of the time. Compliance with the acid rain provisions will occur in two phases. The first phase requires that utilities reduce sulfur dioxide to 5 million tons below the 1980 level by the beginning of 1995. In Phase II, a reduction to 10 million tons below the 1980 level will be completed by the end of the century. In addition, NO_x control devices must also be installed on all existing and future generating plants.

A good deal of the concern over pollution from coal-fired power plants is directed at production of carbon dioxide, which is linked to future global warming. Much of the increase in levels of CO_2 in the atmosphere in modern times has been attributed to combustion of fossil fuels and deforestation. In 1986, according to DOE, the U.S. contribution to total global CO_2 emissions was 22%. Electric power generation accounted for 35% of this amount, transportation 30%, industry 24%, and other sources (residential and commercial) the remainder. Hence, it may well be necessary to have suitable technology available to further mitigate the effects. One of the clean-coal program's principal objectives is the reduction of CO_2 emissions.

Unit power costs in the U.S. declined steadily until about 1970, mostly because of the economies of scale. The technology of electricity generation went through a number of incremental improvements, but the basic processes didn't change much. By 1970, some metallurgical limits had been reached, which prevented a further rise in operating temperatures of coal-fired generating plants. Additional incremental improvements would be fewer.

Thereafter, with passage of the Clean Air Act, costs began to rise because of the expense of emissions reduction and control. Furthermore, the act provided some economic incentives to retain existing plants beyond their normal retirement. New plants with added environmental costs would simply cost more than retaining the older ones. Some of these plants are now expected to last up to 60 years, about a third longer than was projected. Eventually new plants will be required, and they will be inherently more expensive. It is now estimated by DOE that about 40% of the capital investment and about 30% of the total cost of a new coal-fired generating plant goes to the mandated environmental controls.

In spite of this, coal remains the fuel of choice for most new plants. About 56% of the power presently generated comes from coal-fired plants. Utility companies in the U.S. consume about 80% of the coal mined. The expectation is that by the end of the century coal will provide about 60% of the electric power generated.

In the mid-1990s, utilities will be confronting two new problems. The first will be aging hardware, the second diminishing reserve capacity. Both problems are directly related to deferring new plants into the indefinite future.

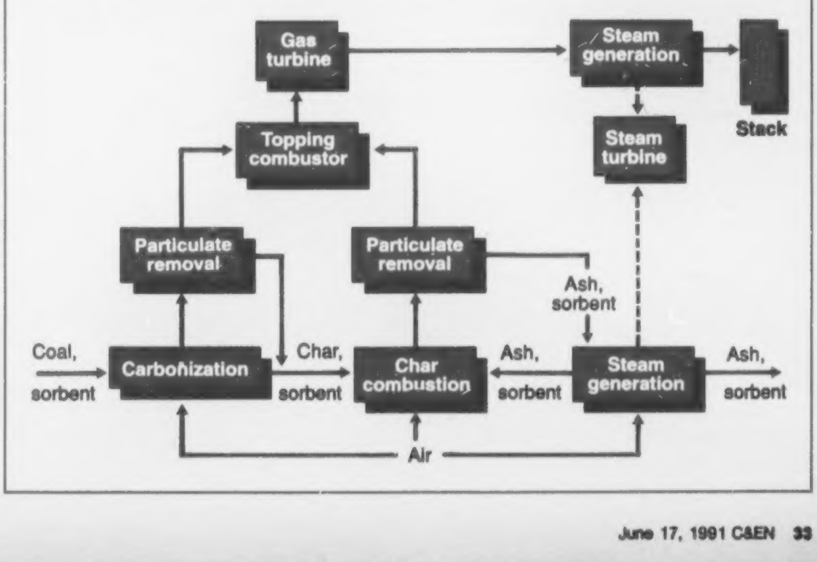
One of the few bright spots in the U.S. energy picture is the abundance of coal reserves. These are estimated by DOE at 268 billion tons. At double present consumption, these reserves are expected to last well into the 21st century and maybe beyond. But however abundant it may be, that coal is expensive to mine, transport, and use in many applications. The coal abundance does give comfort to those concerned with U.S. energy security, although it would be very difficult to do any realistic substitution for other energy sources.

There is a further, not inconsiderable factor in the clean-coal program besides the purely technical. That is the possibility of marketing U.S. coal-consuming technology abroad in the future.

In the clean-coal program, the technology is divided into three categories: preparing the coal for use, using it, and depolluting the products. Combustion is the usual process, although direct conversion to fuels and chemicals is also being considered.

Coal preparation may be physical or chemical (and biological). Physical cleaning is limited to nonchemical impurity removal, mostly washing to separate pyritic sulfur and mineral inclusions. Physical cleaning processes now in hand or in prospect are expected to remove up to 90% of the pyritic sulfur. Chemical cleaning, including the use of biological agents, is more challenging. Organic sulfur removal has remained a particularly tough problem, but

Pressurized fluidized-bed combustor produces low-Btu gas



there have been some encouraging results. Even though the work is still in the early stages, DOE is hoping that up to 90% of organic sulfur will be removable by appropriate chemical cleaning technology.

The object of using coal in boilers is to extract the maximum amount of heat. This usually means burning the coal at a temperature of about 2700 °F. This temperature is regularly achieved with conventional equipment. Advanced combustion equipment is supposed to do this with the addition of SO_x and NO_x control and the removal of particulate matter. The means to do this include the appropriate control of operating variables in the furnace and the introduction of sorbents.

A great variety of systems have been proposed. Some remove SO_x, some remove NO_x, some remove both. Depending on the technical details, up to 70% of NO_x emissions and 95% of SO_x emissions are expected to be removed routinely with advanced combustion technology now under development. Fluid-bed combustion is one of the more promising techniques under investigation.

Pollutants remaining after combustion must be removed downstream of the combustion zone. The usual method at present is the limestone scrubber, which can remove up to 90% of the SO_x but also causes corrosion problems and requires disposal of the sludge. More advanced systems are under development. These include injection of sorbents directly into the existing furnace ductwork or into separate vessels added for this purpose downstream from the firebox. Among the advantages of these systems are the possibility of regenerable sorbents, reduced size, and a benign waste product. They are expensive, however.

Clean-coal program in midst of five-phase effort

Subprogram (phase)	Financial status ($ thousands)		
	Enacted budget	Obligations to date	Costs to date
CCP-I	$ 387,231	$118,485	$ 94,919
CCP-II	535,707	76,753	27,677
CCP-III	545,546	25,636	250
CCP-IV	567,813	0	0
CCP-V	567,813	0	0
SBIR	32,963	14,139	14,139
Program direction	110,527	36,663	31,117
TOTAL	$2,747,600	$271,676	$153,963

Note: CCP = Clean-coal program, SBIR = Small Business Initiative Research program. **Source:** U.S. Department of Energy

One of the more attractive technologies in the clean-coal program is combined-cycle processing in which coal, steam, and oxygen (or air) are combusted to produce fuel gases. The fuel gases are then cleaned and further burned and expanded in a turbine to generate the electric power. Any residual heat may be extracted to generate low-level steam. The great problem is getting the fuel gases clean enough to pass through the turbines without fouling them. The turbine cannot accept appreciable levels of impurities.

Another technology is mild gasification in which the volatile gases from the coal are driven off, leaving behind a char. Gases, the char, and occasional liquids are all valuable fuels and/or feedstocks.

Liquefaction of coal may be direct or indirect, depending on whether synthesis gas is produced. Converting the coal to synthesis gas permits the subsequent employment of such processing as the well-established Rölen, oxo, Fischer-Tropsch, and related chemistries. In recent years, there has been a surge of interest in C_1 chemistry, which employs carbonylation, hydroformylation, and other reactions. This may be revived in the event of another oil production crisis. The principal practitioner of this form of liquefaction is Sasol Technology Pty in South Africa, which utilizes local coal sources to produce that nation's fuel requirements.

Direct liquefaction is the conversion of coal, directly, to liquid fuels via hydrotreating to increase the hydrogen-to-carbon ratio of the hydrocarbons. Coprocessing is a variant of this technology, in which coal and heavy petroleum residues are processed together.

Congress has appropriated a total budget of about $2.75 billion for the five phases of the clean-coal program. The projects in the program are being cofunded by the private sector and DOE. The DOE share amounts to about 38% of the total. The general rule is that the private sector must contribute at least 50% of the total cost. If a project is successful, the government's contribution must be repaid from the profits.

Individual projects of the clean-coal program range from simple conceptual designs to extremely elaborate, full-size demonstration plants. The nature of the projects may be typified by the example of gas reburning and the simultaneous reduction of NO_x and SO_x with sorbent injection.

Gas reburning is a postcombustion technology that is being developed primarily for reduction of NO_x. Up to 85% of the fuel is coal, with the remainder being natural gas or other hydrocarbon fuels. The remainder bypasses the main combustion zone and is injected above the main burners to form a reducing zone in which the NO_x is converted to elemental nitrogen. A finely divided calcium sorbent is injected above the burn zone of the combustor. The expectation is that 60% of the NO_x and 50% of the SO_x will be removed by this technology, even using high-sulfur Illinois coal.

Another project that is related to but distinct from the clean-coal program is a second-generation pressurized fluidized-bed combustor being developed by private concerns under contract with DOE. They include Foster-Wheeler Energy Corp., the Institute of Gas Technology, Gilbert/Commonwealth Inc., Westinghouse Power Generation Business Unit, and Westinghouse Science & Technology.

The pressurized fluidized-bed combustor is a combustion unit intended for use by electric utilities. The intent is to increase generating efficiency with reduced costs despite the necessity of simultaneously reducing emissions and burning high-sulfur coal. The R&D effort is divided into three phases. The first is already complete, the second is now under way, and the third is yet to

Magentohydrodynamics and coal-fired power

Researchers are currently in the third year of a five-year proof-of-concept program on magnetohydrodynamics (MHD), a technique that promises to increase considerably the efficiency of coal-fired power generation. The Department of Energy-funded program will help utilities decide whether to proceed with design and construction of a prototype MHD retrofit plant.

In the MHD process, coal is burned at unusually high temperatures, creating an electrically conducting plasma. After enhancement of its conductivity by addition of a potassium salt (or "seed"), the plasma is directed through a magnetic field within an MHD channel. This produces direct current electric power, which is converted to alternating current for use in the electrical power grid. Because plasma gases leave the MHD channel at a relatively high temperature, they also are used to generate steam for conventional turbine power generation.

In the long term, MHD power plants are projected to be able to convert coal to electricity with efficiencies ranging from 50 to 60%, compared with efficiencies of about 35% for conventional coal-fired power plants. In addition, MHD would provide impressive environmental benefits in terms of reduced emissions of carbon dioxide and other pollutants. The seed material added to the plasma reacts with oxides of sulfur, removing them from the gas stream. In recent tests of an MHD system, more than 95% of sulfur pollutants released from burning high-sulfur coal were captured by the process. Other pollutants, such as nitrogen oxides and particulates, also can be maintained at low levels in the MHD process.

The five-year proof-of-concept program, administered by the Pittsburgh Energy Technology Center (PETC), includes tests on prototype MHD components and on use of MHD exhaust gases for steam generation and preheat of oxidizer gas. These two projects, along with others on regeneration of seed material and MHD retrofit plant design, are intended to prove the feasibility of the concept by the end of 1993. MHD research is also being conducted overseas, in countries that include the U.S.S.R., China, Japan, Poland, Italy, and India.

In the U.S., political support for R&D on the technology is strong, both in Congress and in states where the research is being conducted. For example, $50 million to help defray the cost of an MHD demonstration unit was recently appropriated by the state of Montana.

PETC administrators are optimistic about MHD, pointing out that the technology has shown continuous progress over the years. One MHD project manager says, "The potential for efficiency is unbeatable, and it could almost fly on the environmental attributes alone."

Stu Borman

come. The completed first phase included conceptual design, investigating plant sensitivity to variations in feedstocks and sorbents, preparation for commercialization, and other tasks. The second phase, now in progress, consists of a test program for several components and the analyses of these components and of the test results to establish baseline design data. The final phase will include construction of a 5-MW (electric) system, its evaluation in service, and necessary revisions of the baseline design.

In the plant, the coal is fed to a pressurized carbonizer that produces a low-Btu fuel gas and char. The fuel gas passes through a cyclone and cross-flow filter to remove particulates, which are then burned in a topping combustor to produce the energy required to drive the turbine. The turbine, in turn, drives a compressor and generator that feeds air to the carbonizer, a circulating pressurized fluidized-bed combustor, and a fluidized-bed heat exchanger. The char is burned in the fluidized-bed combustor with excess air. The depleted air from the combustor supports combustion of the fuel gas in the topping combustor. Steam from the heat recovery system drives the steam turbine generator that provides the rest of the electric power from the plant.

The low-Btu gas is produced in the carbonizer by pyrolysis and devolatilization of the coal in a fluidized-bed reactor. Because it operates at low temperatures, this unit also produces residual char. The fuel gas must be treated for removal of sulfurous components by injection of lime-based sorbents into the carbonizer. The sulfur from the hydrogen sulfide and tars is captured thereby as calcium sulfide. Sulfur is captured in situ, thus eliminating the need for downstream heat exchangers and special sulfur recovery apparatus.

Char and calcium sulfide entrained in the fuel gas are removed in a high-temperature filter. The resulting fuel gas is, essentially, particle free. The particulate matter is injected back into the pressurized fluidized-bed combustor.

Based on preliminary data from the first phases, it appears that the second-generation pressurized fluidized-bed plant operates at about 45% efficiency, and the electricity cost is about 22% lower than with a comparable conventional plant.

At a recent technical conference on the problems of energy production and use, a veteran engineer observed that about every 10 years or so the government appears with a new program that reinvents the coal-fired boiler in a new form. He is convinced that the clean-coal program is the latest example. While there is no doubt that the repeated efforts will eventually get something done, he is also of the opinion that faster progress is possible by simply letting the industry alone long enough to "do its own thing." The example he favored was that of the Texaco gasification process, which was developed for synthesis gas production but has found many other applications.

Not all agree with this opinion. The opposing viewpoint is that to manage progress in an era of hyperregulation and environmental threat, it is necessary simultaneously to appease the special interest advocates. It isn't enough to merely progress. It must be done with the protocol of the pork barrel and the media blitz. □

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JUNE 24, 1991

CHEMICAL & ENGINEERING

NEWS

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CHEMICAL & ENGINEERING
NEWS

Volume 69, Number 25
CENEAR 69 (25) 1–96
ISSN 0009-2347

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Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
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Subscription Rates 1991: Printed editions: nonmembers U.S. 1 yr. $95, 2 yr. $171; outside U.S. 1 yr. $131, 2 yr. $243. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3–10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $12. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management: CENTCOM LTD.
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LETTERS

Effects of agent orange

There was a report (C&EN, April 15, page 12) on the results of two recent government studies of the effects of agent orange on Vietnam veterans.

C&EN's analysis of the two reports is misleading. The first report about 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) levels of personnel who participated in Operation Ranch Hand is only a small percentage of the original study group: 866 out of 1242. If one half of the 866 subjects were pilots and copilots, then only 50% of the group (console operators and handlers) were heavily exposed to the herbicides. A poor exposure index and too few study subjects do not lead to statistically significant consequences.

The second part of the article generalizes the results of the Department of Veterans Affairs adipose tissue study of deceased veterans. All 36 subjects are reported to be Vietnam veterans. Eight served off-shore and two arrived in Vietnam long after the spraying ceased. Tissues were drawn from an unrepresented sample of data.

Had operational analysis techniques been applied when conducting the studies, the differences in the disease rates would have been more clear to the public. The report about the two studies is not representative of the total Vietnam veteran population.

Richard S. Christian
Deputy Director for Research & Technology Assessment, Veterans Affairs & Rehabilitation, The American Legion
Washington, D.C.

Future chemistry perspectives

The chemist, an extraordinary breed of scientist, educator, and researcher, has contributed tremendously toward the enhancement of living standards and toward technological advances within the past 100 years. One can hardly find any area of science and technology, health, agriculture and food, alternative energies, manufacture of new products with the preservation of environmental quality in mind, and so forth, that has not been affected by the very important role of chemists.

Such contributions have not, frankly, been fully recognized both in terms of monetary compensation and public image and acknowledgment. It is about time that we, through ACS, take a clearer and more effective stand on these two very important issues. The average number of years of graduate studies beyond a bachelor's degree for a chemistry Ph.D. and an M.D. degree is six and four years, respectively. One could hardly find a doctoral chemistry graduate without having had at least a couple of quality original scientific articles. Nevertheless, everybody knows of the differences in financial compensation and public image that the physicians have achieved.

At the global level, we are entering an era when society at large should and will realize that its most vital treasure is its intellectual resources. I believe we, within ACS, should work in a concerted fashion to bring about similar fruits to our fellow colleagues. This should, in turn, help the chemist shortage beyond the year 2000. It is projected that by the year 2000, we as a nation could suffer a shortfall of as many as over half a million science and engineering professionals if serious measures are not taken now. One of the most critical issues is surely who will replace the currently active scientific community in the years ahead. Many studies indicate that by the year 2000, over three quarters of the net new entrants into the job market will be women and minorities. So we should continue defining our positions and plans to look at providing opportunities and challenges for this majority of our new work force.

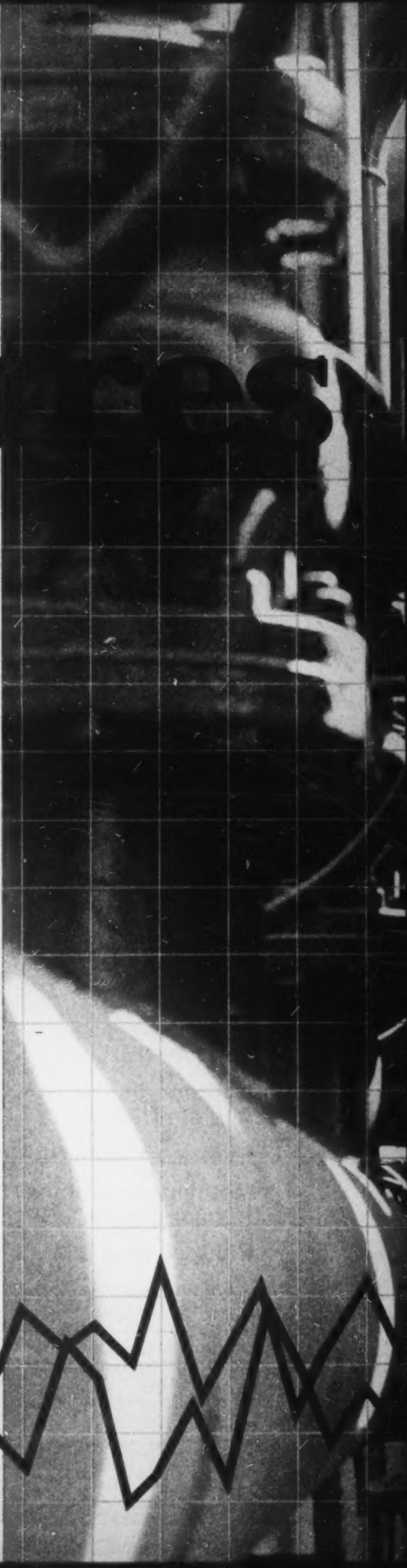
This, the other main issue, is to promote the recruitment and retention of native U.S. chemistry students at various academic levels. I believe the federal and state governments, private and corporate sectors, and the entire system of education—all in partnership—should work together in order to excite, attract, and retain a substantially higher number of students to the science and engineering disciplines in general and chemistry in particular. Industry should further continue participating in this endeavor by developing open houses for students at all levels, offering presentations to educational

Correction

- June 17, page 70: In the agenda for the Committee on Constitution & Bylaws listed in the preliminary program for the combined chemical congress and ACS national meeting in August, urgent action is requested on the dues escalator provisions received on 5/8/91, not the provisions received on 12/26/90.

Facts & Figures

for the chemical industry

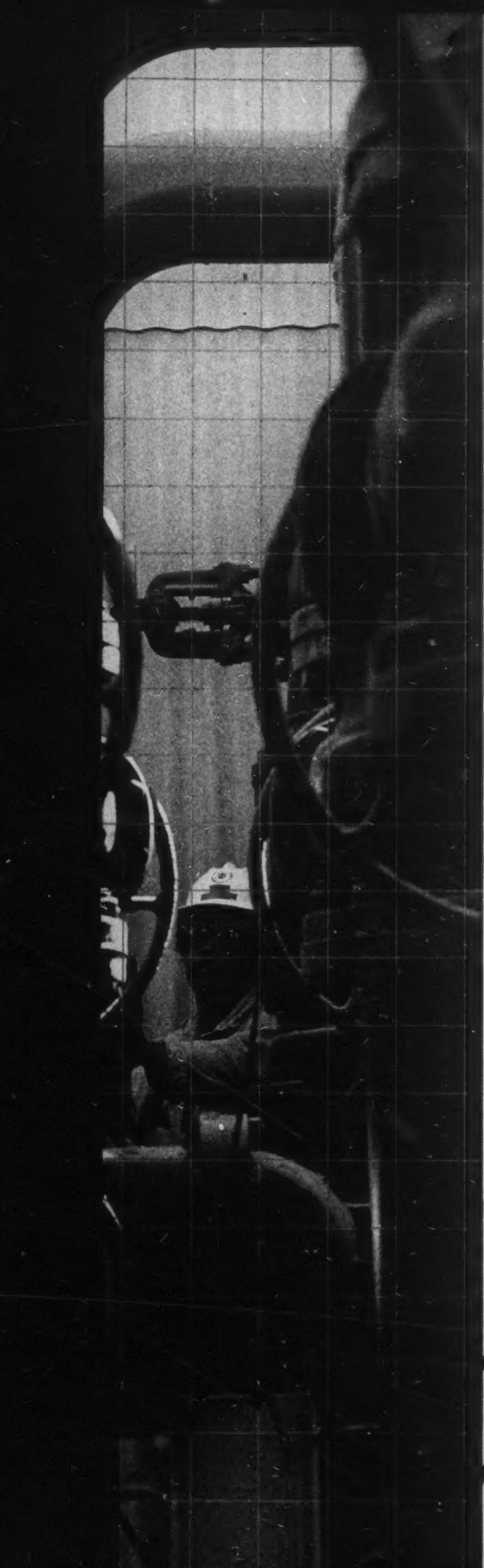


No expansion lasts forever, and, as the data graphed and tabulated on the following pages of C&EN's annual Facts & Figures issue show, 1990 clearly marked the end of the strong growth the U.S. chemical industry enjoyed through much of the late 1980s.

Still, by some measures, 1990 was not a bad year for chemical makers, more of a lackluster one. Sales continued to rise, as they have every year since 1981, though not enough to offset rising raw materials costs. Production posted its second year of only modest expansion, thanks to softening in most important end-use markets for chemicals, particularly housing construction and automobiles. But earnings fell for the second year in a row for the 30 major chemical makers C&EN regularly surveys—22% in 1990.

And the outlook is for more of the same before things get better. With no turnaround yet in major chemicals markets, more plants coming on stream at a time when capacity utilization is already soft, and the prospect of continuing tightness in raw materials supplies, thanks to events in the Middle East, 1991 isn't shaping up as a turnaround year.

The data presented on the following pages illustrate statistically the overall health of the chemical industry both in the U.S. and, to a lesser extent, in several other important chemical-producing nations. The data pulled together here come from a variety of sources, such as government agencies, trade associations, and international organizations, as well as the individual companies that comprise the chemical industry. In many cases, these raw data have been used by C&EN's staff to develop analytical measures and comparisons that help put the industry's recent results into better perspective.



At a glance

Section One: Production

The U.S. chemical industry raised output last year 3%, making 1990 the second year in a row of only modest production increases. Most major sectors of the industry held fairly steady for the year; only plastics, led by 15% increases in output for both polypropylene and low-density polyethylene, showed significant gains. The biggest volume commodity chemicals generally posted gains for the year. **Page 30**

Section Two: Finances

Although sales continued to climb, setting yet another all-time high in 1990, rising raw materials costs and softening capacity utilization ate into profits and profitability for chemical makers. Overall, earnings dropped 22% among the 30 companies C&EN tracks. Capital spending, however, remained strong, and R&D expenditures increased. **Page 39**

Section Three: Employment

The number of people working in the chemical industry was essentially unchanged last year at nearly 1.09 million. Scientists and engineers among that number rose to 78,400 in January 1990, 1% higher than their level a year earlier. Women were 30% of the chemical work force in 1989, compared with 33% for manufacturing workers generally. Among the larger chemical companies, overall employment declined 2% in 1990. **Page 58**

Section Four: Markets

Chemical markets, like the U.S. economy as a whole, were soft in 1990. As the overall economy moved into a recession at year's end, key markets for chemicals—such as new housing and automobiles—were posting only the latest of several poor years. Agriculture, on the other hand, did well in 1990. **Page 62**

Section Five: Foreign Trade

U.S. firms exported almost $39 billion in chemicals last year, setting a record high chemical trade surplus of $16.5 billion. Chemical trade worldwide was strong, up 12% when measured in U.S. dollars, though trade volume grew somewhat less. Germany, long the world's largest exporter and importer of chemicals, strengthened its lead in both categories, thanks to unification. **Page 64**

Section Six: Foreign Chemical Industries

Slowdown was evident in the chemical industry throughout the world in 1990. In Western Europe, drugmakers boosted earnings, but more purely chemical makers did not. Although Japanese production grew for many chemicals, sharp rises in oil costs took their toll in company earnings. Recession cut volume and prices for many Canadian chemicals. And Eastern Europe and the Soviet Union posted their worst year in more than four decades. **Page 66**

1 Production by the U.S. Chemical Industry

Little change in chemical output last year

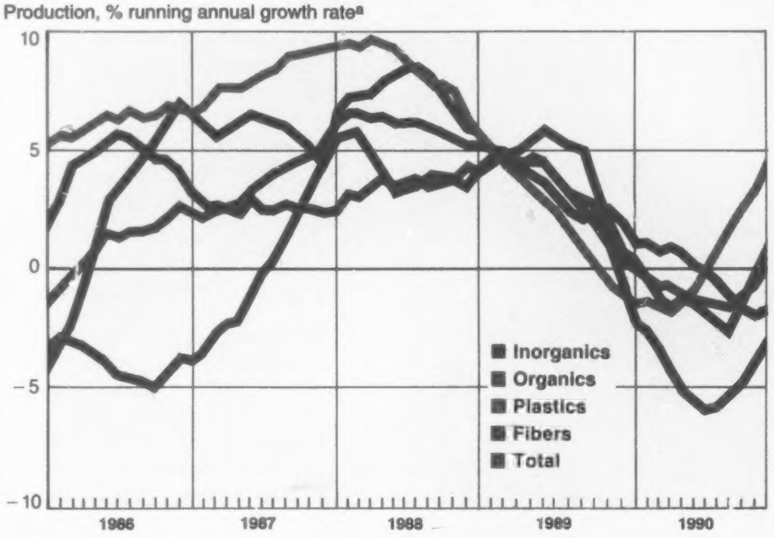
Production by U.S. chemical makers held steady in 1990. The softening of growth that was evident in most sectors of the chemical industry by the end of 1989 never quite became an actual decline in production during 1990. Instead, by most measures, production changed little last year.

According to the Federal Reserve Board, production of chemicals and allied products rose a modest 2% overall in 1990, somewhat less than the 3% gain made in 1989, and right in line with the 2% average annual performance for the group over the past 10 years. The largest volume chemicals, C&EN's Top 50, didn't perform as well, posting a 1.4% gain in 1990 after an annual gain of only 0.8% in 1989. Output for the major organic chemicals rose 1% in 1990, while inorganic production was up 1.6%. Though only inching upward, production for these 50 largest volume chemicals has set new all-time highs each year for the past three.

Plastics had the best year of the major chemical sectors, with overall production up 9% in 1990, according to Federal Reserve Board data, and 8% as measured by the Society of the Plastics Industry. But other synthetic materials fared less well. Synthetic rubber production was off 4% for the year as were man-made fibers, including cellulosics. Fertilizers, too, had a moderately good year, with all three major nutrients posting production gains of 5 to 8% for the 1990 crop year, which ended June 30.

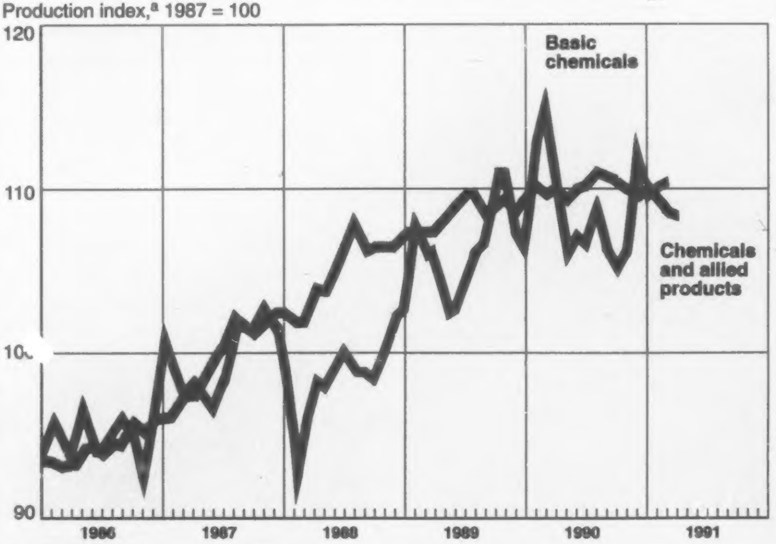
Some of the biggest losses in production were among large-volume inorganic chemicals. Although the group as a whole rose 1.6% for the year, hydrochloric acid fell 26%, calcium chloride fell 28%, and ammonium nitrate fell 10%. In contrast, sodium hydroxide rose 11% and ammonia rose 4%.

As mandated by the Montreal protocol, production of chlorofluorocarbons fell sharply in 1990.



Plastics only chemical sector to show much growth in 1990

[a] Average running annual growth rates in production of major plastics, inorganic and organic chemicals, and all chemicals, and in shipments of man-made fibers. **Sources:** International Trade Commission, Bureau of the Census, Society of the Plastics Industry, Textile Economics Bureau



Chemicals hold on to production gains of late 1980s

[a] Seasonally adjusted. **Source:** Federal Reserve Board

TOP 50 CHEMICALS: Very modest growth last year for both organics and inorganics

Rank			Billions of lb		Common units[b]		Average annual growth			
1990	1989[a]		1990	1989	1990	1989	1989-90	1988-89	1985-90	1980-90
1	1	**Sulfuric acid**	88.56	86.60	44,281 tt	43,301 tt	2.3%	2.8%	2.1%	0 %
2	2	**Nitrogen**	57.32	53.91	791 bcf	744 bcf	6.3	3.0	3.8	5.1
3	3	**Oxygen**	38.99	37.42	471 bcf	452 bcf	4.2	0	3.7	0.9
4	4	**Ethylene**	37.48	34.99	37,480 mp	34,994 mp	7.1	−5.9	4.7	2.7
5	5	**Lime**[c]	34.80	34.36	17,400 tt	17,178 tt	1.3	0.7	1.9	−0.9
6	6	**Ammonia**	33.92	32.72	16,958 tt	16,362 tt	3.6	−2.7	−0.4	−1.5
7	7	**Phosphoric acid**	24.35	23.47	12,175 tt	11,735 tt	3.7	0.5	3.0	1.2
8	9	**Sodium hydroxide**	23.38	20.98	11,688 tt	10,492 tt	11.4	−0.3	1.4	0.1
9	10	**Propylene**	22.12	20.58	22,117 mp	20,575 mp	7.5	−3.1	8.2	4.9
10	8	**Chlorine**	21.88	22.83	10,942 tt	11,413 tt	−4.1	1.4	1.0	−0.4
11	11	**Sodium carbonate**[d]	19.85	19.83	9,925 tt	9,915 tt	0.1	2.9	3.1	1.8
12	13	**Urea**[e]	15.81	15.93	7,905 tt	7,963 tt	−0.7	0.6	3.4	0.1
13	12	**Nitric acid**	15.50	16.70	7,749 tt	8,349 tt	−7.2	4.5	1.0	−1.7
14	14	**Ammonium nitrate**[f]	14.21	15.74	7,107 tt	7,871 tt	−9.7	4.9	1.0	−2.5
15	15	**Ethylene dichloride**	13.30	13.39	13,301 mp	13,385 mp	−0.6	2.7	1.9	1.8
16	16	**Benzene**	11.86	11.94	1,610 mg	1,621 mg	−0.7	1.8	4.8	−2.2
17	17	**Carbon dioxide**[g]	10.98	10.68	5,491 tt	5,339 tt	2.8	5.6	1.9	6.2
18	18	**Vinyl chloride**	10.65	10.14	10,652 mp	10,137 mp	5.1	11.9	2.4	5.1
19	19	**Ethylbenzene**	8.99	9.24	8,988 mp	9,238 mp	−2.7	−7.0	4.0	1.6
20	21	**Styrene**	8.02	8.34	8,018 mp	8,338 mp	−3.8	−7.2	1.0	1.6
21	22	**Methanol**	7.99	8.17	7,987 mp	8,168 mp	2.2	0.3	9.8	1.1
22	20	**Terephthalic acid**[h]	7.69	8.43	7,692 mp	8,427 mp	−8.7	−17.7	3.5	2.4
23	23	**Formaldehyde**[i]	6.41	5.89	6,413 mp	5,894 mp	8.8	−6.1	2.7	1.4
24	30	**Methyl *tert*-butyl ether**[j]	6.30	8.23	6,302 mp	8,229 mp	−23.4	44.9	27.2	na
25	25	**Toluene**[k]	6.10	5.81	841 mg	801 mg	5.0	−8.5	3.8	−1.9
26	26	**Xylene**	5.70	5.80	791 mg	805 mg	−1.7	5.8	1.4	−1.4
27	29	**Ethylene oxide**	5.58	5.03	5,581 mp	5,032 mp	10.9	−15.5	0.6	0.7
28	28	***p*-Xylene**	5.20	5.35	5,201 mp	5,345 mp	−2.7	−4.6	1.7	2.1
29	27	**Ethylene glycol**	5.03	5.46	5,028 mp	5,462 mp	−7.9	−1.0	3.8	1.4
30	31	**Ammonium sulfate**	4.99	4.69	2,495 tt	2,347 tt	6.3	0.6	3.6	1.6
31	24	**Hydrochloric acid**	4.68	6.35	2,341 tt	3,177 tt	−26.3	20.3	−3.5	−2.1
32	32	**Cumene**	4.31	4.43	4,312 mp	4,427 mp	−2.6	−0.6	5.2	2.2
33	34	**Acetic acid**	3.76	3.29	3,756 mp	3,294 mp	14.0	4.3	5.3	2.4
34	35	**Potash**[l]	3.62	3.52	1,640 tmt	1,595 tmt	2.8	4.9	4.8	−3.1
35	33	**Phenol**[m]	3.51	3.81	3,512 mp	3,807 mp	−7.7	6.9	4.8	3.2
36	36	**Propylene oxide**	3.20	3.20	3,200 mp	3,200 mp	0	2.9	5.9	6.1
37	37	**Butadiene**[n]	3.16	3.12	3,156 mp	3,122 mp	1.1	−1.5	6.2	1.2
38	39	**Acrylonitrile**	3.03	2.36	3,029 mp	2,363 mp	28.2	−9.4	5.2	5.2
39	38	**Carbon black**	2.87	2.91	2,868 mp	2,913 mp	−1.5	−0.1	2.2	1.2
40	42	**Vinyl acetate**	2.55	2.55	2,546 mp	2,553 mp	−0.3	−0.3	3.8	2.8
41	43	**Cyclohexane**	2.47	2.27	2,468 mp	2,274 mp	8.5	−1.0	8.3	2.3
42	41	**Aluminum sulfate**	2.42	2.49	1,208 tt	1,244 tt	−2.9	1.0	−1.0	−0.6
43	40	**Acetone**	2.22	2.53	2,221 mp	2,525 mp	−12.0	9.6	4.4	0.7
44	44	**Titanium dioxide**	2.16	2.20	1,079 tt	1,101 tt	−2.0	7.7	4.6	4.2
45	46	**Sodium silicate**	1.76	1.67	878 tt	834 tt	5.3	2.7	4.9	0.9
46	47	**Adipic acid**	1.64	1.64	1,640 mp	1,640 mp	0	2.5	2.5	1.1
47	48	**Sodium sulfate**[o]	1.47	1.51	733 tt	755 tt	−2.9	−7.6	−2.4	−4.3
48	45	**Calcium chloride**[p]	1.38	1.92	690 tt	962 tt	−28.3	32.0	−2.9	−3.5
48	49	**Isopropyl alcohol**	1.38	1.47	1,380 mp	1,474 mp	−6.4	6.1	2.2	−2.8
48	50	**Caprolactam**	1.38	1.31	1,380 mp	1,308 mp	5.2	4.0	5.0	4.3
TOTAL ORGANICS			**216.82**	**214.68**			**1.0%**	**−1.4%**	**4.6%**	**2.1%**
TOTAL INORGANICS			**409.07**	**402.51**			**1.6%**	**2.0%**	**2.1%**	**0.5%**
GRAND TOTAL			**625.89**	**617.19**			**1.4%**	**0.8%**	**2.9%**	**1.0%**

a Revised. b tt = thousands of tons, bcf = billions of cubic feet, mp = millions of pounds, mg = millions of gallons, tmt = thousands of metric tons. c Except refractory dolomite. d Natural and synthetic. e 100% basis. f Original solution. g Liquid and solid only. h Includes both acid and ester without double counting. i 37% by weight. j Production data for earlier years unavailable. k All grades. l K_2O basis. m Synthetic only. n Rubber grade. o High and low purity. p Solid and liquid. na = not available.

PRODUCTION: Like manufacturing as a whole, most chemicals rose only slightly in 1990

Industrial production indexes, 1987 = 100	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	Annual change 1989–90	Annual change 1980–90
Total index	109.2	108.1	105.4	100.0	95.3	94.4	92.8	84.9	81.9	85.7	84.1	1%	3%
Manufacturing, total	109.9	108.9	105.8	100.0	94.3	91.6	89.3	80.9	76.6	80.3	78.8	1	3
Nondurable manufacturing	107.8	106.4	103.6	100.0	94.9	91.5	90.8	87.0	82.5	84.5	83.1	1	3
Chemicals and products	110.3	108.5	105.4	100.0	94.6	91.4	91.4	87.5	81.8	89.2	87.8	2	2
Chemicals and synthetic materials	107.2	106.5	102.5	100.0	93.9	92.2	92.8	88.6	79.4	91.2	86.3	1	2
Basic chemicals	108.6	106.6	98.3	100.0	95.1	96.1	96.9	92.1	86.5	96.9	96.5	2	1
Alkalies and chlorine	99.5	103.2	96.0	100.0	92.1	93.6	95.3	87.9	82.1	94.6	101.5	−4	0
Industrial gases	109.2	108.0	104.1	100.0	98.8	92.8	97.5	85.9	80.1	91.2	91.5	1	2
Inorganic pigments	104.3	111.0	102.6	100.0	96.2	95.1	89.0	87.3	79.1	90.7	90.6	−6	1
Inorganic chemicals, nec	110.1	105.7	96.4	100.0	94.7	97.2	98.0	94.3	89.2	98.7	96.8	4	1
Industrial organic chemicals	107.1	109.2	103.1	100.0	95.1	94.1	93.4	89.9	81.0	97.0	92.8	−2	1
Synthetic materials	106.5	103.1	104.4	100.0	91.6	86.9	88.9	84.3	71.8	79.5	71.2	3	4
Plastics materials	115.8	106.7	106.8	100.0	88.2	84.1	81.1	74.4	64.4	68.3	64.2	9	6
Synthetic rubber	88.6	92.4	105.0	100.0	109.3	114.4	132.8	124.1	110.5	114.5	110.8	−4	−2
Man-made fibers	92.7	98.7	99.5	100.0	93.7	86.6	93.3	92.3	76.4	91.7	74.9	−6	2
Chemical products	113.3	110.1	107.5	100.0	95.9	90.2	89.0	86.6	83.0	85.4	87.6	3	3
Drugs and medicines	114.0	108.1	107.2	100.0	96.7	88.5	86.9	86.1	82.7	80.9	80.2	5	4
Soaps and toiletries	112.3	111.1	107.9	100.0	96.7	91.3	90.6	91.4	89.2	97.7	103.5	1	1
Paints	99.5	104.8	103.9	100.0	97.5	95.7	91.8	84.6	78.8	84.1	87.0	−5	1
Agricultural chemicals	105.1	108.2	107.2	100.0	88.5	96.1	102.0	87.5	88.8	102.3	97.2	−3	1
Petroleum products	108.2	106.1	103.4	100.0	98.9	92.6	92.8	89.6	89.3	94.1	99.0	2	1
Rubber and plastics products	110.2	108.9	105.9	100.0	90.8	85.8	83.8	74.3	65.9	66.6	61.7	1	6

nec = not elsewhere classified. **Source:** Federal Reserve Board

MINERALS: Only potash, which is largely imported, showed strong growth in 1990

Thousands of tons	1990[a]	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	Annual change 1989–90	Annual change 1980–90
Bromine, sold or used[b]	193	193[a]	180	168	155	160	193	185	200	189	189	0%	0%
Calcium chloride, production[c,d]	690	801[a]	731	658	780	940	1,036	912	853	917	811	−14	−2
Lime, sold or used[e]	17,400	17,178	16,658	15,733	14,474	15,690	15,922	14,867	14,075	18,890	19,037	1	−1
Lithium, consumption[d,f]	3.0	3.0	3.0	2.7	2.6	2.5	3.2	2.2	2.0	3.2	3.0	0	0
Phosphate rock													
Marketable production	50,700	54,913	50,000	45,145	4[illegible],445	56,035	54,230	46,928	41,241	59,110	59,982	−8	−2
Exports	7,700	8,644	8,920	9,319	8,651	10,071	12,707	13,239	10,849	11,458	15,737	−11	−7
Potash (K_2O equivalent)[g]													
Production	1,810	1,758	1,677	1,391	1,325	1,429	1,724	1,575	1,967	2,377	2,468	3	−3
Imports	4,590	3,759	4,648	4,490	4,643	5,063	5,323	4,894	4,253	5,287	5,481	22	−2
Apparent consumption	5,680	4,960	5,803	5,609	5,338	5,893	6,638	6,231	5,647	6,849	6,999	15	−2
Salt, production[h]	39,400[d]	39,278	39,170	36,943	37,282	39,217	39,181	32,973	37,665	38,899	40,396	0	nc
Evaporated[i]	6,700[d]	7,070	7,203	6,896	6,316	6,162	6,334	5,276	5,273	6,206	6,358	−5	nc
Rock[i]	14,200[d]	14,140	12,750	12,230	13,333	13,990	13,653	11,870	12,806	11,866	11,806	0	nc
Salt in brine[i]	18,500[d]	18,068	19,218	17,817	17,633	19,065	19,195	15,827	19,586	20,826	22,231	2	nc
Sodium carbonate, production[j]	10,098	9,915	9,632	8,891	8,438	8,511	8,511	8,467	7,819	8,281	8,275	2	2
Sulfur, production[k]	12,484	12,778	11,845	11,616	12,221	12,797	11,742	10,240	10,788	13,388	13,080	−2	0
Apparent consumption[l]	14,082	13,983	14,012	12,481	11,669	13,192	13,976	12,112	11,088	14,093	15,056	1	−1
Frasch, production	3,968	4,286	3,499	3,530	4,457	5,524	4,622	3,530	4,[illegible]41	6,997	7,044	−7	−6
Recovered elemental, production	7,110	7,176	7,103	6,791	6,411	5,857	5,747	5,462	4,8[illegible]5	4,695	4,490	−1	5
Other, production	1,405	1,316	1,243	1,296	1,354	1,416	1,372	1,249	1,293	1,695	1,547	7	−3

a Preliminary. b Elemental bromine sold as such or used in preparation of bromine compounds by primary producers. c 75% $CaCl_2$ equivalent. d Estimated. e Includes Puerto Rican production. f Lithium content basis. g Includes muriate and sulfate of potash, potassium magnesium sulfate, and parent salts; excludes other chemical compounds containing potassium. h Figures for 1980 are total obtained by all recovery methods that was sold or used by domestic producers (slightly different from U.S. production); figures for 1980–81 include Puerto Rican production. i Sold or used as such. j Natural and synthetic for 1980–86, natural only in 1987–90. k Sulfur content basis. l Calculated from shipments plus imports minus exports (sulfur content basis). nc = not comparable. **Sources:** Bureau of Mines, Bureau of the Census

1 Production by the U.S. Chemical Industry

ORGANIC CHEMICALS: Biggest volume organics generally did well in otherwise mixed field

Millions of lb unless otherwise noted	Production											Annual change	
	1990[a]	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1989–90	1980–90
Acetic acid, synthetic	3,755	3,294	3,159	3,246	2,728	2,897	2,619	2,807	2,748	2,705	2,977	14%	2%
Acetone	2,221	2,524	2,303	1,846	1,910	1,788	1,862	1,859	1,694	2,144	2,076	−12	1
Acrylonitrile	3,029	2,362	2,609	2,452	2,182	2,349	2,219	2,146	2,035	1,997	1,830	28	5
Aniline	947	1,016	1,029	829	624	716	786	663	557	634	659	−7	4
Benzene, mg[b,c]	1,615	1,631	1,608	1,575	1,362	1,283	1,318	1,232	1,052	1,308	1,534	−1	1
Bisphenol A	1,141	1,241	1,340	1,000	956	949	762	643	480	555	530	−8	8
1,3-Butadiene[d]	3,155	3,121	3,169	2,931	2,546	2,340	2,452	2,353	1,915	2,986	2,799	1	1
1-Butanol	1,269	1,751	1,194[a]	1,155	881	716	908	833	730	809	790	−28	5
Caprolactam	1,379	1,307	1,261	1,156	1,109	1,089	1,027	977	793	928	905	5	4
Carbon tetrachloride	271	na	761	672	627	646	713	573	587	726	710	—	−9
Chloroform	497	588	524	462	422	275	405	362	299	405	273	−15	6
Cumene	4,311	4,426	4,455	4,105	3,745	2,627	3,754	3,345	2,743	3,309	3,459	−3	2
Cyclohexane	2,467	2,273	2,297	2,276	2,070	1,657	1,994	1,656	1,275	1,820	1,964	9	2
Dioctyl phthalate	302	306	344	343	296	275	301	300	266	304	353	−1	−2
Ethanol, synthetic	na	549	562	574	529	649	1,060	1,077	1,023	1,317	1,451	—	—
Ethanolamines[e]	679	667	608	627	543	537	504	468	416	429	376	2	6
Ethylbenzene	8,987	9,235	9,929	9,346	9,020	7,386	7,562	7,876	6,656	7,813	7,642	−3	2
Ethyl chloride	na	162	152	155	164	171	290	282	339	324	396	—	—
Ethylene	37,474	34,988	37,204	34,951	32,859	29,847	31,383	28,680	24,501	29,418	28,667	7	3
Ethylene dichloride	13,299	13,383	13,028	12,197	12,940	12,101	10,710	11,506	7,619	9,974	11,108	−1	2
Ethylene glycol	5,027	5,461	5,517	5,183	4,771	4,178	4,823	4,425	4,309	4,143	4,386	−8	1
Ethylene oxide	5,580	5,031	5,953	4,785	5,430	5,430	5,699	5,534	4,987	4,937	5,220	11	1
2-Ethylhexanol	596	612	743	662	571	536	541	387	325	389	367	−3	5
Formaldehyde, 37%[f]	6,412	5,893	6,280	5,733	5,549	5,606	5,815	5,465	4,817	5,721	5,555	9	1
Isobutylene	1,145	1,193	1,244	1,035	1,124	na	883	760	741	1,035	1,052	−4	1
Isopropyl alcohol	1,380	1,474	1,389	1,371	1,301	1,235	1,394	1,209	1,380	1,669	1,836	−6	−3
Maleic anhydride	418	475	448	382	359	394	359	299	260	293	304	−12	3
Methanol, synthetic	7,986	8,167	8,142	7,537	7,205	5,003	8,186	7,982	7,555	8,577	7,153	−2	1
Methyl chloride	498	461	597	373	605	410	482	409	366	405	362	8	3
Methyl ethyl ketone	473	450	482	672	600	537	543	531	468	614	692	5	−4
Methyl methacrylate	1,207	1,161	1,100	1,029	943	858	917	844	721	592	564	4	8
Methylchloroform	785	783	724	694	652	869	675	586	595	611	587	0	3
Methylene chloride	471	482	504	516	566	467	607	584	532	891	780	−2	−5
Perchloroethylene	384	481	498	473	414	678	573	547	585	691	765	−20	−7
Phenol, synthetic[g]	3,512	3,806	3,562	3,351	3,115	2,841	2,889	2,638	2,023	2,578	2,568	−8	3
Phthalic anhydride	941	917	999	1,035	863	820	870	838	684	870	818	3	1
Propylene[h]	22,113	20,571	21,224	19,019	16,522	14,887	15,559	13,959	12,535	13,482	13,676	8	5
Propylene glycol	800	805	840	747	573	500	462	484	400	473	488	−1	5
Styrene, monomer	8,017	8,337	8,984	8,014	7,888	7,622	7,709	6,802	5,942	6,679	6,856	−4	2
Terephthalic acid, dimethyl ester[i]	7,690	8,426	10,234	7,601	6,257	6,490	5,912	5,626	4,843	6,235	6,054	−9	2
Toluene, mg[b,j]	843	806	892	967	611	698	728	780	714	852	1,010	5	−2
Vinyl acetate	2,545	2,552	2,561	1,813	1,710	2,112	2,024	1,963	1,876	1,936	1,922	0	3
Vinyl chloride	10,650	10,135	9,058	8,402	8,439	9,463	6,084	6,875	4,902	6,874	6,466	5	5
***o*-Xylene**	943	983	971	940	788	675	688	781	802	918	995	−4	−1
***p*-Xylene**	5,200	5,344	5,601	5,155	5,035	4,779	4,264	4,114	3,391	4,532	4,238	−3	2

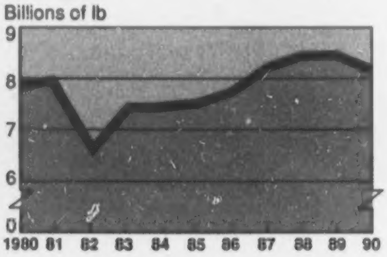
Note: mg = millions of gallons. a Preliminary. b Tar distillers and coke-oven operators not included. c Specification grades. d Rubber grade. e Mono-, di-, and triethanolamines. f By weight. g Does not include data for coke ovens and gas-retort ovens. h All grades. i Includes both acid and dimethyl ester (DMT), without double counting. j High-purity toluene, includes material used in blending motor fuel. **na** = not available. **Source:** International Trade Commission

INORGANICS: Mixed results mark production for both the year and the decade

Thousands of tons unless otherwise noted	Production											Annual change	
	1990^{a}	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1989–90	1980–90
Aluminum sulfate^{b}	1,208	1,243	1,237	1,227	1,222	1,268	1,129	1,119	1,154	1,294	1,286	−3%	−1%
Ammonia, 100%^{c,d}	16,958	16,362	16,821	16,098	14,487	17,319	16,692	14,072	15,801	19,044	19,653	4	−1
Ammonium nitrate, 100%^{e}	7,107	7,871	7,504	6,547	6,091	7,149	7,146	6,240	7,091	8,861	9,128	−10	−2
Ammonium sulfate, 100%^{d,f}	2,495	2,347	2,333	2,189	2,080	2,093	2,067	1,956	1,768	2,185	2,136	6	2
Chlorine gas^{g}	10,943	11,413	11,257	11,078	10,436	10,402	10,700	9,960	9,176	10,763	11,421	−4	0
Hydrochloric acid, 100%^{h}	2,341	3,177	3,228	2,996	2,413	2,807	2,732	2,468	2,450	2,574	2,888	−26	−2
Hydrogen, bcf, 100%^{i,j}	188	208	177	173	136	121	109	103	88	105	107	−10	6
Hydrogen peroxide, 100%^{k}	204	204	168	153	152	144	139	117	108	111	116	0	6
Nitric acid, 100%^{k}	7,749	8,349	7,991	7,225	6,734	7,631	7,726	6,768	7,390	9,093	9,231	−7	−2
Nitrogen gas, bcf, 100%^{i,l}	791	744	722	685	677	665	661	560	483	490	479	6	5
Oxygen, bcf, 100%^{i,j}	471	452	452	405	383	393	375	346	349	431	431	4	1
Phosphoric acid, 100% P_2O_5	12,175	11,737	11,659	10,599	9,578	10,607	11,370	9,767	8,253	9,958	10,848	4	1
Phosphorus^{m}	356	353	343	344	364	359	386	366	361	426	432	1	−2
Sodium chlorate, 100%	308	290	267	289	267	259	295	323	291	297	312	6	0
Sodium hydroxide, 100%	11,688	10,491	10,533	11,553	10,691	10,811	10,914	10,039	9,385	10,621	11,625	11	0
Sodium phosphate^{n}	568^{o}	610^{o}	549	586	617	625	675	669	651	696	727	−7	−2
Sodium silicate^{p}	878	833	812	952	791	692	685	710	664	771	805	5	1
Sodium sulfate, 100%^{q}	733	755	819	799	837	1,203	901	914	864	1,111	1,140	−3	−4
Sulfuric acid, 100%^{r}	44,281	43,301	42,580	39,256	35,993	39,890	41,802	36,583	33,233	40,742	44,158	2	0
Titanium dioxide, 100%^{s}	1,079	1,101	1,022	968	931	860	835	760	660	761	727	−2	4
Urea	7,905	7,963	7,914	7,433	6,264	6,975	7,433	6,137	6,470	8,062	7,830	−1	0

Note: bcf = billions of cubic feet. a Preliminary. b Commercial, 17% Al_2O_3; includes municipalities. c Synthetic anhydrous. d Excludes by-product ammonia liquor and ammonium sulfate. e Original solution. f Synthetic and noncoke by-product. g Includes quantities liquefied for use, storage, or shipment. h Includes anhydrous hydrochloric acid production. i High- and low-purity gas. j Liquid and gas; excludes amounts vented and used as fuel, and amounts produced in petroleum refineries for captive use. k Includes unspecified amounts produced but not withdrawn from the system. l Excludes amounts produced and consumed in making synthetic ammonia or ammonia derivatives. m Elemental, white (yellow), and red. n Tripolyphosphate (100% $Na_5P_3O_{10}$). o Includes tetrabasic (pyro) phosphate. p Soluble silicate glass (water glass), solid and liquid (anhydrous); excludes amounts produced and consumed in making meta-, ortho-, and sesquisilicates. q Anhydrous, high and low purity, and Glauber's salt. r Gross (new and fortified). s Composite and pure. **Sources:** Department of Commerce, International Trade Commission

Synthetic noncellulosic fibers output



SYNTHETIC FIBERS: Production declines for all fibers except polyolefins

Millions of lb	Production											Annual change	
	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1989–90	1980–90
NONCELLULOSIC FIBERS													
Acrylic^{a}	506	543	588	592	616	631	671	671	624	691	779	−7%	−4%
Nylon^{b}	2662	2740	2669	2689	2514	2343	2412	2419	1927	2332	2358	−3	1
Olefin^{c}	1822	1639	1588	1494	1393	1249	997	906	723	785	748	11	9
Polyester	3195	3594	3681	3541	3305	3341	3392	3544	3196	4176	3989	−11	−2
CELLULOSIC FIBERS													
Acetate^{d}	505	580	614	605	619	558	199	229	196	261	316	−13	−5
Rayon							421	401	388	509	490		
TOTAL	**8690**	**9096**	**9140**	**8921**	**8447**	**8122**	**8092**	**8168**	**7027**	**8754**	**8680**	**−4%**	**0%**

a Includes modacrylic. b Excludes aramid in 1983–87. c Includes olefin yarn and monofilaments and olefin and vinyon staple, tow, and fiberfill. d Includes diacetate and triacetate; excludes production for cigarette filters. **Source:** Fiber Economics Bureau

SYNTHETIC RUBBER: Output decline, which began in 1989, accelerated in 1990

	Production											Annual change	
Thousands of metric tons	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1989–90	1980–90
Ethylene-propylene	256	260	263	254	230	215	215	175	123	176	144	−2%	6%
Nitrile	56	69	76	69	59	53	67	55	45	66	63	−19	−1
Polybutadiene	403	411	407	371	336	330	359	333	288	342	311	−2	3
Styrene-butadiene rubber	853	874	909	850	792	735	958	904	876	1032	1074	−2	−2
Other[a]	546	647	679	638	596	505	556	468	498	404	423	−16	3
TOTAL	**2114**	**2261**	**2335**	**2182**	**2013**	**1838**	**2155**	**1935**	**1830**	**2022**	**2015**	**−7%**	**0%**

a Includes butyl, polychloroprene, polyisoprene, silicone, and other synthetic elastomers. Some values are estimated. **Source:** Rubber Manufacturers Association

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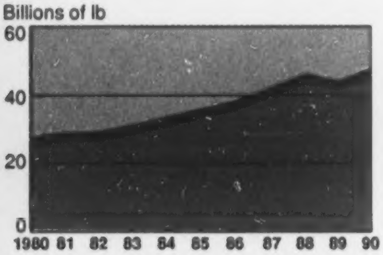
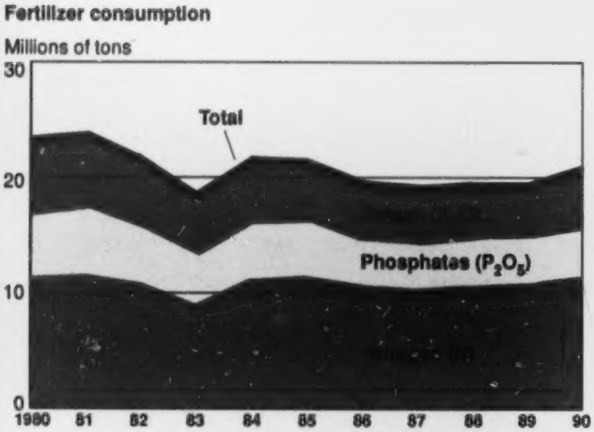
Plastics production



PLASTICS: Production of major resins moved ahead last year

	Production											Annual change	
Millions of lb[a]	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1989–90	1980–90
THERMOSETTING RESINS													
Epoxy[b]	499	509	486	433	398	385	406	334	286	336	315	−2%	5%
Melamine	202	222	207	212	173	192	210	180	158	179	167	−9	2
Phenolic[c]	2,946[d]	2,879[d]	3,066[d]	2,869[d]	2,735[d]	2,621[d]	2,502[d]	2,477[d]	2,006[d]	2,333[d]	1,499	2	nc
Polyester[e]	1,221	1,319	1,404	1,367	1,271	1,223	1,232	1,084	865	997	947	−7	3
Urea	1,496	1,477	1,425	1,382	1,271	1,210	1,199	1,172	998	1,165	1,165	1	3
TOTAL	**6,364**	**6,408**	**6,588**	**6,263**	**5,648**	**5,631**	**5,549**	**5,247**	**4,313**	**5,010**	**4,093**	**−1%**	**nc%**
THERMOPLASTIC RESINS													
Polyethylene													
Low density[f]	11,176	9,695	10,397	9,599	8,903	8,889	8,413	8,041	7,503	7,693	7,291	15	4
High density[g]	8,334	8,102	8,400	7,995	7,182	6,671	6,085	5,689	4,928	4,695	4,405	3	7
Polypropylene	8,318	7,238	7,274	6,647	5,812	5,139	4,940	4,433	3,477	3,955	3,648	15	9
Styrene polymers													
Polystyrene	5,012	5,104	5,187	4,780	4,470	4,054	3,838	3,570	3,191	3,621	3,521	−2	4
Styrene-acrylonitrile	134	113	148	126	92	87	99	93	91	107	111	19	2
Acrylonitrile-butadiene-styrene and other styrene polymers[h]	2,335	2,394	2,418	2,254	2,196	2,036	2,127	1,889	1,380	1,745	1,705	−2	3
Polyamide, nylon type	556	569	566	507	465	399	396	321	228	312	274	−2	7
Vinyl resins													
Polyvinyl chloride and copolymers	9,088	8,478	8,350	7,971	7,256	6,772	6,760	6,067	5,326	5,707	5,470	7	5
Other vinyl resins[i]	226	220	222	212	195	190	187	186	177	208	196	3	1
Thermoplastic polyester	1,879	1,630	1,652	1,394	1,175	965	899	778	648	609	na	15	—
TOTAL	**47,058**	**43,543**	**44,614**	**41,485**	**37,746**	**35,202**	**33,744**	**31,067**	**26,949**	**28,652**	**26,621**	**8%**	**6%**

Note: Totals are for those products listed and exclude some small-volume plastics. a Dry-weight basis unless otherwise specified. b Unmodified. c Includes other tar acid resins. d Gross-weight basis. e Unsaturated. f Density 0.940 and below. g Density above 0.940. h Includes styrene-butadiene copolymers and other styrene-based polymers. i Includes polyvinyl butyral, polyvinyl formal, and polyvinylidene-chloride. na = not available. nc = not comparable. **Source:** Society of the Plastics Industry


Fertilizer consumption

Note: Years ending June 30. Sources: Department of Agriculture, Fertilizer Institute

FERTILIZERS: All major nutrients had increased use in 1990 crop year

	Consumption											Annual change	
Thousands of tons	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1989–90	1980–90
Nitrogen (N)	11,076	10,593	10,512	10,210	10,424	11,493	11,092	9,127	10,983	11,924	11,407	5%	0%
Phosphates (P_2O_5)	4,345	4,117	4,129	4,008	4,178	4,658	4,901	4,138	4,814	5,434	5,432	6	−2
Potash (K_2O)	5,203	4,838	4,973	4,837	5,053	5,553	5,797	4,831	5,631	6,320	6,245	8	−2
TOTAL	**20,624**	**19,548**	**19,614**	**19,055**	**19,655**	**21,704**	**21,790**	**18,096**	**21,428**	**23,678**	**23,084**	**6%**	**−1%**

Note: Years ending June 30. Source: Fertilizer Institute

FERTILIZER PRODUCTION: Phosphate rock declined, ammonia and potash showed little change

									Annual change	
Thousands of tons	1990	1989	1988	1987	1986	1985	1984	1983	1989–90	1983–90
NITROGEN PRODUCTS										
Ammonia	14,167	14,192	14,136	13,357	12,565	16,594	16,613	13,361	0%	1%
Ammonium nitrate	2,579	2,528	2,765	2,472	2,250	3,178	3,365	3,232	2	−2
Ammonium sulfate	2,395	2,327	2,260	2,153	2,058	2,343	2,078	1,969	3	2
Urea	4,231	4,253	4,501	4,253	3,564	3,975	4,889	4,112	−1	0
Nitrogen solutions	4,750	5,644	6,999	5,988	5,945	7,928	7,999	6,385	−16	−3
PHOSPHATE PRODUCTS										
Diammonium phosphate	13,660	13,507	11,575	9,537	7,492	10,800	12,358	10,264	3	4
Monoammonium phosphate	2,252	1,991	1,818	1,679	1,416	1,641	1,654	1,423	13	6
Concentrated superphosphate	1,998	1,777	2,032	2,049	2,127	2,570	2,404	2,684	12	−3
Phosphate rock	44,311	47,676	42,220	39,330	36,227	49,348	47,465	40,664	−7	1
Phosphoric acid (P_2O_5)	11,344	10,962	10,234	8,903	8,085	9,837	10,899	9,182	3	3
POTASH PRODUCTS										
Potassium chloride	2,350	2,316	2,243	1,810	1,715	1,713	2,168	1,928	1	3

Note: Figures are based on Fertilizer Institute surveys and may not represent the entire industry. Source: Fertilizer Institute

PESTICIDES: Strong growth in 1989 helps insecticides recover from declines of early 1980s

Millions of lb	Production											Annual change	
	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1988–89	1979–89
Herbicides[a]	697	702	556	725	756	716	604	623	839	806	657	−1%	1%
Insecticides[b]	424	352	379	342	370	350	306	379	448	506	617	20	−4
Fungicides[c]	111	110	105	113	109	123	106	111	143	156	155	1	−3
TOTAL	**1232**	**1164**	**1040**	**1180**	**1235**	**1189**	**1017**	**1113**	**1430**	**1468**	**1429**	**6%**	**−1%**

a Includes plant growth regulators. b Includes rodenticides, soil conditioners, and fumigants. c Includes dithiocarbamates. **Source:** International Trade Commission

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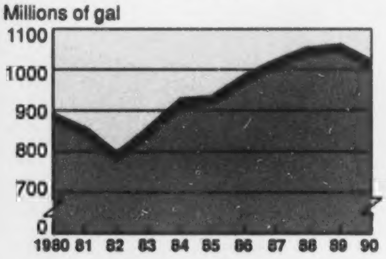
Paints and coatings shipments

COATINGS: Decline in major uses drops overall volume below 1989 level



Millions of gal	Shipments											Annual change	
	1990[a]	1989[a]	1988	1987	1986	1985	1984	1983	1982	1981	1980	1989–90	1980–90
Architectural	517	552	536	527	501	477	457	433	374	417	439	−6%	2%
Product[b]	324	358	366	340	350	317	336	294	280	312	316	10	0
Special purpose	161	159	154	145	136	145	145	130	129	129	135	1	2
TOTAL	**1002**	**1069**	**1056**	**1013**	**987**	**939**	**938**	**857**	**783**	**858**	**890**	**−6%**	**1%**

a Preliminary. b For original equipment manufacturers. **Source:** Department of Commerce

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AEROSOLS: Production growth of 1980s has stalled

Millions of units	Production											Annual change	
	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1989–90	1980–90
Personal products	1050	1015	1100	964	952	879	832	747	628	645	637	3%	5%
Household products	680	680	650	640	635	630	603	586	556	575	580	0	2
Automotive and industrial products	415	475	440	379	375	342	337	303	286	302	310	−13	3
Paints and finishes	350	350	331	307	297	290	307	300	295	313	310	0	1
Insect sprays	190	197	190	190	193	190	184	180	166	173	150	−4	2
Food products	175	175	157	140	136	140	138	132	131	145	130	0	3
Animal products	8	8	8	22	22	15	16	19	19	14	15	0	−6
Miscellaneous	15	12	31	80	18	23	15	15	13	28	30	25	−7
TOTAL	**2883**	**2912**	**2907**	**2722**	**2628**	**2509**	**2432**	**2282**	**2094**	**2195**	**2162**	**−1%**	**3%**

Source: Chemical Specialties Manufacturers Association

CHLOROFLUOROCARBONS: Production for all major types falls sharply

Millions of lb	Production											Annual change	
	1990[a]	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1989–90	1980–90
Chlorodifluoromethane (F-22)	306	343	333	275	271	235	254	236	174	252	227	−11%	3%
Dichlorodifluoromethane (F-12)	209	392	414	335	322	302	337	290	258	325	295	−47	−3
Trichlorofluoromethane (F-11)	135	192	249	196	202	176	185	215	140	163	158	−30	−2
All other fluorinated hydrocarbons[b]	na	385	379	354	344	306	337	279	na	na	na	—	—
TOTAL	**na**	**1312**	**1374**	**1162**	**1139**	**1019**	**1113**	**1020**	**na**	**na**	**na**	**—**	**—**

a Preliminary. b Includes other fluorohalogenated hydrocarbons. na = not available. **Source:** International Trade Commission

Chemical earnings, profitability decline

Last year brought few surprises for the chemical industry. It was expected that 1990 would be a continuation of the lackluster second half of 1989, and that is just what it turned out to be, although there were some extras that perhaps made the year somewhat worse than some industry observers predicted.

Chief among these was perhaps the runup in raw materials costs brought on by the Middle East situation. This was coupled with already weakening capacity utilization caused by softening in such end-use markets as housing construction and automobiles and other durable goods, and by new plants coming on stream. The result was increased pressure on profits in the chemical industry and a classic cost-price squeeze.

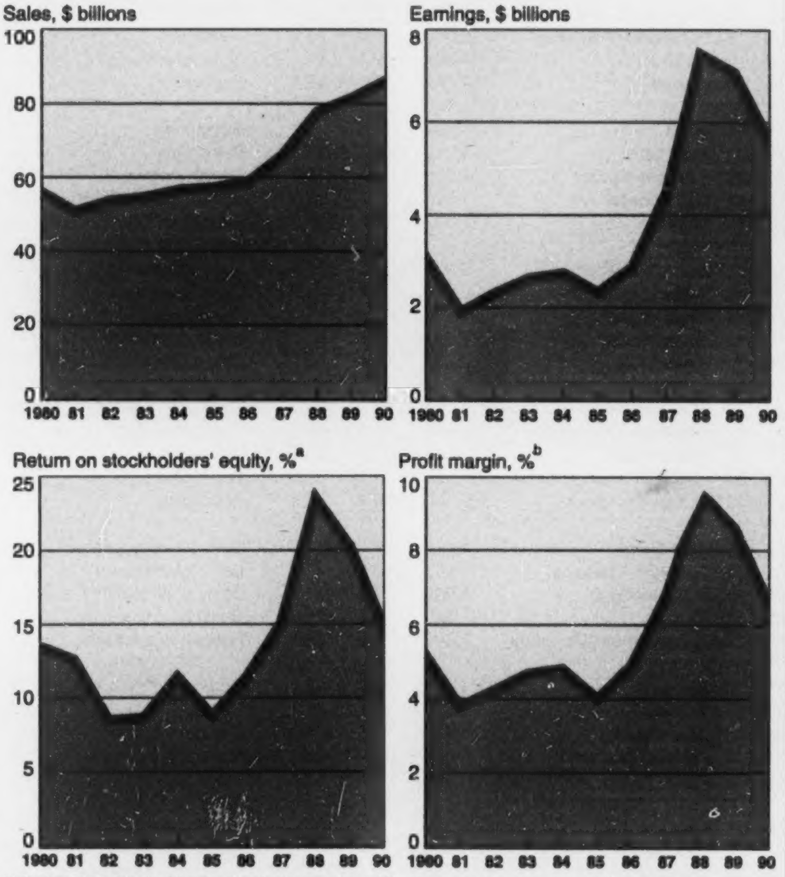
Combined earnings for the 30 major chemical companies regularly surveyed by C&EN dropped 22% in 1990 from the year-earlier level. This is the fourth earnings contraction since 1980, with the others occurring in 1981, 1985, and the small drop-off registered in 1989. But the 22% drop is the largest since earnings fell about 35% in 1981.

Spurred in part by exports and by price increases, sales at the 30 companies held up, however. Sales in 1990 rose about 7% from their 1989 levels, making it yet another record year.

Naturally, 1990 profitability followed earnings on the downward course. Return on year-end stockholders' equity fell to 14.0% in 1990 from 20.2% in 1989. And the average profit margin for the 30 chemical firms dropped to 6.3% last year from 8.6% the year before.

This, however, is not quite so bad as it seems since both measures are still reasonably good on a historical basis. Although during the past few years the industry has gotten fairly spoiled by high returns, profitability in 1990 was still higher than any year during the past decade (except for 1987 through 1989).

Only sales continue to grow as 1990 marks second year of decline for chemical earnings, profitability



Note: Based on data for 30 major chemical companies. a After-tax earnings as a percentage of year-end stockholders' equity. b After-tax earnings as a percentage of sales.

Thus far, the current year is a continuation of 1990. Earnings are continuing on their downward slide from year-earlier levels, causing profitability also to continue downward.

Chemical producers are hoping for an upturn in the second half of this year and, indeed, there are some signs that this may be more than wishful thinking. First-quarter earnings and profitability were both higher than they had been in the fourth quarter of 1990, showing some increased business activity. And some markets, such as residential construction, have in the past couple of months shown some signs of strengthening. Others, however, are still in the doldrums.

However, even if producers are correct in forecasting a better second half, the best they can hope for is that 1991 will be flat when compared with the previous 12 months.

TOP 100 CHEMICAL PRODUCERS: Profits fall substantially for many of the largest firms

Rank 1990	Rank 1989		Chemical sales 1990 ($ millions)	Change from 1989	Chemical sales as % of total sales	Industry classification	Chemical operating profits[a] ($ millions)	Change from 1989	Chemical operating profits as % of total profits	Operating profit margin[b]	Identifiable chemical assets ($ millions)	Chemical assets as % of total assets	Operating return on chemical assets[c]
1	1	**Du Pont**	$15,571	2.1%	38.9%	Diversified	$1968	−28.9%	40.1%	12.6%	$13,788	36.2%	14.3%
2	2	**Dow Chemical**	14,690	3.6	74.3	Basic chemicals	1925	−45.7	68.3	13.1	13,604	56.8	14.2
3	3	**Exxon**	11,153	5.6	9.6	Petroleum	737	−54.1	8.1	6.6	8,548	9.7	8.6
4	4	**Union Carbide**	7,621[d]	−0.4	100.0	Basic chemicals	1033	−17.0	100.0	13.6	7,613	87.2	13.6
5	5	**Monsanto**	5,711	−1.2	63.5	Basic chemicals	624	−32.8	68.6	10.9	4,831	52.3	12.9
6	6	**Hoechst Celanese**	5,499	−2.8	93.5	Basic chemicals	427	−25.9	105.4	7.8	na	na	na
7	8	**General Electric**	5,167[d]	4.8	8.8	Diversified	1017	−3.8	13.2	19.7	7,973	5.2	12.8
8	7	**Occidental Petroleum**	5,040	−2.4	23.2	Petroleum	636	−39.8	23.4	12.6	5,494	27.8	11.6
9	9	**BASF**	4,366	−2.1	81.1	Basic chemicals	na	na	na	na	na	na	na
10	10	**Amoco**	4,087	−4.4	12.9	Petroleum	252	−66.1	6.4	6.2	3,646	11.5	6.9
11	11	**Mobil**	4,084	1.1	7.7	Petroleum	397	−47.1	7.6	9.7	3,265	7.8	12.2
12	12	**Shell Oil**	3,718	−3.0	15.2	Petroleum	519	−44.8	26.6	14.0	3,952	13.9	13.1
13	13	**Eastman Kodak**	3,588	1.9	19.0	Photo equipment	602	−6.4	21.2	16.8	3,952	16.4	15.2
14	15	**W. R. Grace**	3,570	10.8	52.9	Specialty chemicals	431	6.9	77.9	12.1	2,756	44.3	15.6
15	14	**Chevron**	3,325	9.1	8.0	Petroleum	44	−91.7	0.9	1.3	2,622	7.5	1.7
16	17	**Arco Chemical**	2,830	6.3	100.0	Basic chemicals	469	−19.1	100.0	16.6	3,739	100.0	12.5
17	18	**Rohm & Haas**	2,824	6.1	100.0	Basic chemicals	351	22.3	100.0	12.4	2,414	100.0	14.5
18	16	**Allied-Signal**	2,786	−6.9	22.6	Diversified	287	−19.2	39.3	10.3	1,896	18.1	15.1
19	19	**Air Products[e]**	2,614	5.3	90.3	Basic chemicals	441	3.6	108.0	16.9	3,132	80.3	14.1
20	21	**Bayer USA**	2,380	3.6	40.0	Diversified chemicals	91[f]	−24.9	61.2	3.8[f]	na	na	na
21	32	**Rhône-Poulenc**	2,278	42.4	100.0	Specialty chemicals	na	na	na	na	na	na	na
22	22	**American Cyanamid**	2,255	0.6	49.3	Basic chemicals	195	−15.0	62.2	8.7	1,832	36.0	10.7
23	23	**Ashland Oil[e]**	2,245	0.7	25.0	Petroleum	70	−45.3	21.1	3.1	856	16.7	8.2
24	30	**Hercules**	2,193	3.6	68.5	Basic chemicals	167	22.8	69.0	7.6	1,860	50.3	9.0
25	20	**Phillips Petroleum**	2,120	−13.4	15.6	Petroleum	448	−31.3	21.3	21.1	1,797	14.8	24.9
26	42	**Ciba-Geigy**	1,976	10.0	52.0	Specialty chemicals	na	na	na	na	na	na	na
27	24	**Quantum Chemical**	1,959	−6.9	73.8	Basic chemicals	242	−42.7	95.1	12.4	2,235	69.4	10.8
28	25	**B. F. Goodrich**	1,940	−1.9	79.7	Basic chemicals	129	−50.4	85.2	6.7	1,521	64.3	8.5
29	31	**Akzo**	1,893	1.0	100.0	Basic chemicals	152	11.6	100.0	8.0	na	na	na
30	26	**Lyondell Petrochemical**	1,889	19.6	29.1	Petroleum products	na	na	na	na	na	na	na
31	29	**Alcoa**	1,842[d]	5.7	17.2	Nonferrous metals	1319	11.5	121.3	71.6	2,855	25.0	46.2
32	27	**Texaco**	1,723	−5.2	4.1	Petroleum	60	−85.0	2.5	3.5	1,308	5.0	4.6
33	33	**Dow Corning**	1,718	9.1	100.0	Specialty chemicals	171[f]	5.1	100.0	10.0[f]	na	na	na
34	34	**National Starch**	1,670	6.4	100.0	Specialty chemicals	254	12.3	100.0	15.2	1,448	100.0	17.6
35	35	**FMC**	1,624	5.4	43.6	Machinery	192	−15.1	45.4	11.8	1,469	49.6	13.0
36	36	**Ethyl**	1,591	4.7	100.0	Basic chemicals	308	9.0	100.0	19.4	1,383	100.0	22.3
37	28	**Atochem**	1,540	−13.4	100.0	Basic chemicals	na	na	na	na	na	na	na
38	56	**Degussa**	1,435	61.9	75.3	Specialty chemicals	na	na	na	na	na	na	na
39	45	**Lubrizol**	1,335	18.8	91.9	Specialty chemicals	398	24.1	90.8	29.8	887	79.5	44.9
40	42	**Huntsman Chemical**	1,300	8.3	100.0	Basic chemicals	na	na	na	na	na	na	na
41	40	**Tenneco**	1,298	6.0	8.9	Diversified	167	40.3	11.5	12.9	1,409	7.5	11.9
42	38	**Olin**	1,269	−1.2	49.0	Basic chemicals	45	−74.1	30.6	3.5	945	50.6	4.8
43	39	**Unocal**	1,236	−3.1	10.5	Petroleum	115	−47.0	23.7	9.3	671	6.9	17.1
44	48	**Nalco Chemical**	1,212	13.2	100.0	Specialty chemicals	211	16.3	100.0	17.4	1,037	100.0	20.3
45	44	**PPG Industries**	1,150	−2.1	19.1	Glass products	231	−10.1	25.4	20.1	1,076	17.6	21.5
46	52	**Cabot[e]**	1,107	16.3	66.2	Basic chemicals	147	32.1	89.6	13.3	1,100	63.5	13.4
47	41	**IMC Fertilizer[g]**	1,106	−9.5	100.0	Agrochemicals	171	−33.5	100.0	15.5	1,585	100.0	10.8
48	61	**Great Lakes Chemical**	1,066	34.6	100.0	Specialty chemicals	290	43.7	100.0	27.2	1,406	100.0	20.6
49	67	**Imcera Group[g]**	1,025	54.7	71.9	Specialty chemicals	104	99.2	92.5	10.2	1,090	51.1	9.6
50	54	**Morton International[g]**	1,021	9.2	62.3	Specialty chemicals	140	−3.4	58.0	13.7	na	na	na

Rank 1990	Rank 1989		Chemical sales 1990 ($ millions)	Change from 1989	Chemical sales as % of total sales	Industry classification	Chemical operating profits[a] ($ millions)	Change from 1989	Chemical operating profits as % of total profits	Operating profit margin[b]	Identifiable chemical assets ($ millions)	Chemical assets as % of total assets	Operating return on chemical assets[c]
51	—	**Reichhold Chemicals**	$1000	na	100.0%	Specialty chemicals	na	na	na	na	na	na	na
52	50	**Solvay America**	997	0%	100.0	Basic chemicals	na	na	na	na	na	na	na
53	51	**Aristech**	974	−2.2	100.0	Basic chemicals	na	na	na	na	na	na	na
54	55	**Farmland Industries[h]**	965	9.2	28.6	Agricultural supplies	$84	−7.0%	52.5%	8.7%	$412	30.4%	20.4%
55	57	**International Flavors**	963	10.7	100.0	Specialty chemicals	243	11.8	100.0	25.3	1129	100.0	21.5
56	53	**Terra Chemicals**	961	1.3	100.0	Agrochemicals	na	na	na	na	na	na	na
57	47	**Georgia Gulf**	932	−15.6	100.0	Basic chemicals	229	−23.6	100.0	24.5	457	100.0	50.1
58	49	**NL Industries**	907	−9.4	100.0	Basic chemicals	251	−18.6	100.0	27.7	1967	100.0	12.8
59	58	**CF Industries**	903	5.5	100.0	Agrochemicals	49	78.5	100.0	5.4	801	100.0	6.1
60	46	**Freeport-McMoRan**	825	−25.3	52.2	Agrochemicals	52	−52.3	17.2	6.3	880	24.5	5.9
61	66	**American Petrofina**	813	22.8	21.1	Petroleum	160	15.7	61.8	19.7	523	18.4	30.6
62	60	**Uniroyal Chemical**	808	0.4	100.0	Specialty chemicals	106	2.4	100.0	13.4	1178	100.0	9.2
63	59	**Engelhard**	807	−0.7	27.4	Diversified	100	3.8	71.0	12.4	874	66.2	11.4
64	65	**H. B. Fuller[i]**	792	5.2	100.0	Specialty chemicals	52	12.8	100.0	6.6	490	100.0	10.6
65	64	**Witco**	769[j]	0.4	47.1	Specialty chemicals	82	363.7	66.9	10.7	477	40.5	17.2
66	62	**Vista Chemical[e]**	719	−7.7	100.0	Basic chemicals	151	−32.7	100.0	20.9	na	na	na
67	69	**Kerr-McGee**	642	8.4	17.4	Petroleum	123	−1.6	33.8	19.2	658	18.9	18.7
68	72	**Betz Laboratories**	597	15.5	100.0	Specialty chemicals	104	19.0	100.0	17.4	427	100.0	24.4
69	79	**Loctite**	555	17.2	100.0	Specialty chemicals	48	17.0	100.0	8.6	489	100.0	9.7
70	76	**Merck**	551	11.9	7.2	Drugs	68	14.5	2.6	12.3	510	6.4	13.3
71	74	**Pfizer**	546	7.5	8.5	Drugs	29	−26.2	2.5	5.3	418	4.6	6.9
72	77	**Ferro**	513	5.5	45.6	Specialty materials	10	−46.2	14.5	2.0	288	42.0	3.5
73	70	**Sterling Chemical[e]**	506	−12.9	100.0	Basic chemicals	88	−43.4	100.0	17.5	352	100.0	25.1
74	75	**Hoffmann-La Roche**	500	0	20.8	Drugs	na	na	na	na	na	na	na
75	63	**Nova**	489	−27.9	100.0	Basic chemicals	−17	def	100.0	def	221	100.0	def
76	73	**Sun Co.**	486	−4.6	3.7	Petroleum	na	na	na	na	na	na	na
77	68	**GAF**	481	−19.8	52.2	Specialty chemicals	164	−4.4	88.8	34.0	na	na	na
78	—	**Hüls**	465	3.6	100.0	Specialty chemicals	na	na	na	na	na	na	na
79	83	**Union Camp**	460	12.8	16.2	Diversified	22	66.2	6.1	4.9	352	8.0	6.4
80	84	**Sigma-Aldrich**	440	22.6	83.2	Specialty chemicals	104	14.3	94.1	23.5	485	88.7	21.4
81	81	**Dexter**	438	−0.1	48.3	Specialty chemicals	38	23.3	90.7	8.7	280	36.7	13.7
82	78	**Borden Chemicals**	421	−9.7	100.0	Basic chemicals	68	−29.1	100.0	16.1	544	100.0	12.4
83	82	**Vulcan Materials**	409	−4.9	37.0	Nonmetallic minerals	72	−16.2	39.3	17.7	na	na	na
84	85	**Stepan**	390	12.5	100.0	Specialty chemicals	21	83.1	100.0	5.5	247	100.0	8.7
85	87	**Crompton & Knowles**	311	10.7	79.7	Specialty chemicals	43	19.6	72.2	13.9	239	84.5	18.1
86	86	**First Mississippi[g]**	295	−4.1	59.3	Agrochemicals	23	−14.8	97.4	7.8	173	33.9	13.3
87	90	**Calgon Carbon**	285	12.4	100.0	Basic chemicals	62	10.1	100.0	21.9	285	100.0	21.9
88	89	**Petrolite[k]**	283	2.9	94.2	Specialty chemicals	17	−9.4	93.3	5.9	209	82.8	8.0
89	88	**Chemed**	275	−0.9	45.9	Specialty chemicals	23	−38.6	56.3	8.5	139	42.4	16.9
90	92	**Mississippi Chemical[g]**	253	21.1	100.0	Farm cooperative	5	−89.6	100.0	1.9	289	100.0	1.7
91	90	**Georgia-Pacific**	247	−2.4	2.0	Wood products	na	na	na	na	na	na	na
92	94	**Quaker Chemical**	201	10.9	100.0	Specialty chemicals	22	17.6	100.0	10.7	152	100.0	14.1
93	—	**Sequa Corp.**	201	42.4	10.8	Diversified	30	54.4	20.2	14.7	112	5.9	26.5
94	93	**Sherex**	177	−5.9	100.0	Specialty chemicals	na	na	na	na	na	na	na
95	98	**Lawter International**	150	10.3	100.0	Specialty chemicals	28	23.0	100.0	18.5	154	100.0	18.0
96	95	**LeaRonal[l]**	141	−10.5	100.0	Specialty chemicals	14	−10.4	100.0	10.0	81	100.0	17.3
97	99	**Cambrex Corp.**	134	2.0	100.0	Specialty chemicals	4	−32.3	100.0	3.3	na	na	na
98	97	**Eagle-Picher**	123	−19.4	17.5	Diversified	16	7.4	33.3	13.0	76	18.2	21.1
99	—	**Aceto[g]**	122	8.1	100.0	Specialty chemicals	7	−2.4	100.0	5.4	68	100.0	9.6
100	—	**Sybron**	120	na	100.0	Specialty chemicals	na	na	na	na	na	na	na

a Operating income is sales less administrative expenses and cost of sales. **b** Chemical operating profit as a percentage of sales. **c** Chemical operating profit as a percentage of identifiable chemical assets. **d** Chemical sales include significant amounts of nonchemical products. **e** Fiscal year ended Sept. 30. **f** Chemical net income. **g** Fiscal year ended June 30. **h** Fiscal year ended Aug. 31. **i** Fiscal year ended Nov. 30. **j** Does not include all chemical sales. **k** Fiscal year ended Oct. 31. **l** Fiscal year ended Feb. 28, 1990. **na** = not available. **def** = deficit.

FINANCIAL ANALYSIS: Decline evident in many chemical company performance measures

		Profit margin[a]	Return on investment[b]	Debt as % of debt plus equity	% total sales abroad[c]	% total assets abroad[d]	Sales per employee[e]	Dividends as % of net income	CAPITAL SPENDING[f]		R&D as % of sales	Sales as % of assets	Net plant as % of gross plant
									as % of sales	as % of net plant			
SALES OVER $1 BILLION													
Air Products[g]	1990	7.9%	3.9%	36.1%	24.5%	35.5%	$207	33.4%	16.2%	18.8%	2.5%	74.2%	49.6%
	1989	8.4	4.3	37.1	23.6	30.8	187	31.2	15.7	18.7	2.7	78.5	49.9
American Cyanamid	1990	2.4	1.7	13.1	39.6	27.2	143	118.9	8.2	19.7	10.1	89.8	51.5
	1989	6.1	5.0	16.5	38.6	24.6	136	41.1	8.2	22.6	8.4	97.1	51.4
Cabot[g]	1990	4.2	3.4	45.7	41.8	36.0	279	41.8	10.4	19.9	2.1	96.6	57.3
	1989	0.9	1.0	44.1	32.8	12.7	352	166.1	9.9	25.9	1.8	136.7	56.1
Dow Chemical	1990	7.0	5.1	37.4	52.0	45.4	318	51.4	10.7	25.7	5.7	82.5	43.1
	1989	14.1	10.1	32.6	54.1	44.9	283	23.2	9.6	22.2	5.0	79.4	44.1
Ethyl	1990	9.2	12.5	39.5	21.2	4.9	441	108.0	6.0	22.4	2.6	37.6	50.8
	1989	14.4	13.2	35.6	31.3	3.8	276	26.3	7.8	20.5	4.0	27.0	48.8
B. F. Goodrich	1990	4.8	4.3	13.2	24.7	18.6	165	53.8	10.0	21.9	3.0	102.8	60.3
	1989	7.1	6.3	18.5	26.7	18.6	203	34.6	9.9	24.2	2.7	106.4	59.6
W. R. Grace	1990	3.0	2.8	50.7	36.9	34.1	138	59.5	7.6	20.9	2.2	108.5	50.2
	1989	4.2	3.9	48.6	34.8	31.0	132	46.6	7.9	21.8	2.0	108.8	49.6
Great Lakes Chemical	1990	13.2	11.5	9.2	53.1	42.7	na	11.5	4.6	13.3	2.7	75.8	59.5
	1989	15.5	13.2	16.1	40.1	49.6	na	11.1	5.1	14.7	3.4	72.2	56.6
Hercules	1990	3.0	2.4	23.6	27.8	18.6	161	109.4	8.5	18.8	2.9	86.5	47.3
	1989	def	def	23.3	25.4	17.0	133	def	9.5	20.7	2.5	84.6	48.4
Imcera Group	1990	4.1	3.7	47.8	34.4	17.0	133	def	9.5	20.7	2.5	84.6	48.4
	1989	11.2	7.1	44.5	25.8	27.3	148	43.8	6.0	14.6	5.3	66.9	69.2
Lubrizol	1990	13.2	12.2	6.8	56.8	43.7	280	27.5	5.4	21.9	5.2	129.6	39.0
	1989	7.7	6.9	7.4	52.4	40.3	230	54.8	5.3	20.4	5.7	127.1	39.0
Monsanto	1990	6.1	4.9	28.8	36.8	32.4	219	44.3	8.3	21.5	7.7	97.4	45.8
	1989	7.8	6.7	27.2	35.6	28.5	206	32.5	7.0	19.1	6.9	100.9	45.7
Morton International[h]	1990	8.2	7.4	20.6	30.4	25.6	169	30.7	6.8	17.2	2.9	90.4	59.7
	1989	6.9	6.5	4.6	31.1	26.4	167	na	9.4	23.8	2.7	103.1	59.7
Nalco Chemical	1990	10.8	10.5	38.3	28.2	20.4	207	48.2	9.5	27.4	3.7	116.9	49.6
	1989	11.2	10.8	32.5	27.1	19.4	195	47.9	8.1	24.6	3.8	114.1	48.7
Olin	1990	3.2	2.8	39.5	7.8	10.9	171	58.3	7.2	22.6	2.5	138.9	36.1
	1989	4.9	4.2	36.1	7.2	9.3	163	34.7	5.7	18.2	2.6	131.8	36.0
PPG Industries	1990	7.9	5.8	31.1	34.3	33.5	172	37.0	6.9	12.8	3.6	98.6	54.3
	1989	8.1	6.2	33.3	30.9	29.7	162	35.6	9.4	17.9	4.1	101.6	55.2
Quantum	1990	0.8	0.6	104.2	na	na	na	0	17.3	22.7	1.8	82.4	69.5
	1989	4.3	3.4	107.9	na	na	na	1121.1	21.8	33.2	1.7	88.9	70.0
Rohm & Haas	1990	7.3	5.5	32.7	43.7	32.4	219	38.2	14.6	29.6	6.3	104.5	50.2
	1989	6.6	5.2	21.5	43.2	32.1	204	43.8	14.5	33.5	6.6	108.4	47.9
Union Carbide	1990	4.0	2.6	49.6	36.4	32.3	202	44.8	9.8	17.2	2.5	87.3	48.5
	1989	6.6	4.7	46.6	33.7	40.7	190	24.4	9.0	17.1	2.1	102.3	48.1
Witco	1990	4.2	4.4	28.2	19.8	20.2	225	56.4	5.6	19.3	1.6	138.4	48.8
	1989	2.2	2.3	29.2	18.9	16.4	216	103.3	4.4	16.9	1.6	139.4	48.3
MEDIAN 1990		**5.5%**	**4.4%**	**34.4%**	**34.4%**	**32.3%**	**$205**	**44.6%**	**8.3%**	**20.4%**	**2.9%**	**93.5%**	**50.2%**
MEDIAN 1989		**7.0**	**5.7**	**32.6**	**31.3**	**26.4**	**193**	**34.7**	**8.7**	**20.6**	**3.1**	**102.0**	**49.2**

2 Finances of the U.S. Chemical Industry

		Profit margin[a]	Return on investment[b]	Debt as % of debt plus equity	% total sales abroad[c]	% total assets abroad[d]	Sales per employee[e]	Dividends as % of net income	CAPITAL SPENDING[f]		R&D as % of sales	Sales as % of assets	Net plant as % of gross plant
									as % of sales	as % of net plant			
SALES LESS THAN $1 BILLION													
Betz Laboratories	1990	11.0%	11.3%	31.0%	19.0%	22.0%	$162	56.2%	9.6%	24.6%	3.9%	139.7%	57.9%
	1989	10.8	12.1	35.2	17.8	18.9	151	55.4	10.2	30.7	3.7	139.9	54.6
Calgon Carbon	1990	13.9	12.4	5.3	39.2	43.5	190	15.4	16.7	33.0	2.0	99.9	76.4
	1989	13.9	13.3	9.9	37.3	30.7	191	12.5	10.4	25.8	1.9	108.4	75.5
Chemed	1990	3.1	6.3	42.2	12.2	13.7	87	122.4	2.5	19.7	0.6	161.7	55.2
	1989	4.9	9.8	41.5	11.0	11.8	93	70.6	2.7	21.4	0.6	158.1	56.5
Crompton & Knowles	1990	7.7	10.4	37.4	18.7	19.2	218	31.2	4.2	21.3	2.2	138.0	62.1
	1989	6.9	11.2	29.4	17.3	21.5	212	27.9	3.8	26.4	2.2	163.3	56.1
First Mississippi[h]	1990	0.9	0.5	39.7	24.0	na	na	135.0	13.0	20.8	na	97.2	45.0
	1989	3.8	2.1	30.6	17.7	na	na	34.6	24.7	38.2	na	90.8	44.8
H. B. Fuller[i]	1990	2.7	3.7	30.9	46.3	54.2	142	25.7	4.0	15.6	2.0	161.9	61.3
	1989	2.1	3.1	35.1	44.9	50.8	140	34.9	5.4	21.9	2.1	165.5	63.5
Georgia Gulf	1990	10.2	17.9	263.9	na	na	868	0	6.2	27.1	na	204.1	68.0
	1989	17.4	35.3	66.1	na	na	818	12.5	4.9	25.9	na	233.5	69.7
International Flavors	1990	16.3	11.4	0.0	70.1	46.6	230	52.5	4.3	15.5	6.0	85.3	51.7
	1989	15.9	11.9	0.0	69.2	47.0	206	52.6	3.8	14.1	6.0	89.7	53.1
Loctite	1990	12.1	13.0	9.8	55.0	65.5	151	31.2	5.1	27.4	3.9	113.5	55.6
	1989[h]	11.9	14.0	13.8	57.9	62.0	130	26.4	3.5	22.8	3.8	126.1	53.7
Petrolite[j]	1990	4.4	3.4	2.3	31.3	37.5	na	96.7	5.8	14.8	4.1	118.9	44.5
	1989	2.4	2.0	1.1	30.5	35.0	na	178.1	6.5	18.0	4.1	121.5	44.0
Quaker	1990	7.0	8.4	5.2	41.1	35.0	187	30.5	6.3	27.3	na	132.2	55.3
	1989	7.1	8.9	5.9	43.4	32.1	185	29.8	4.2	20.7	na	138.2	53.0
Sigma-Aldrich	1990	13.5	11.3	16.1	28.1	29.0	129	14.3	6.1	16.9	na	96.9	66.2
	1989	14.5	12.0	17.1	21.9	26.4	116	14.3	11.7	29.3	na	93.4	71.3
Stepan	1990	3.7	3.8	48.3	11.7	13.6	297	22.0	9.8	26.8	3.4	157.7	49.6
	1989	2.3	2.3	49.2	na	na	301	37.2	9.8	27.8	2.9	160.8	48.7
Sterling Chemical[g]	1990	11.7	14.8	37.1	35.4	na	na	93.6	3.9	9.2	na	143.8	78.8
	1989	17.9	28.6	37.6	35.0	na	na	42.5	9.9	26.6	na	176.5	84.7
MEDIAN 1990		**10.2%**	**10.4%**	**16.1%**	**33.4%**	**33.6%**	**$189**	**31.2%**	**5.8%**	**21.3%**	**3.0%**	**132.2%**	**55.6%**
MEDIAN 1989		**10.6**	**11.2**	**29.4**	**35.0**	**32.1**	**188**	**34.9**	**5.4**	**25.8**	**2.8**	**138.2**	**54.6**

Note: Net income is from continuing operations, excluding extraordinary and nonrecurring items where possible. **a** Net income as a percentage of sales. **b** Net income as a percentage of current assets plus gross plant. **c** Consolidated sales only. **d** Foreign identifiable assets as a percentage of total assets. **e** Thousands of dollars. **f** Actual spending on construction of new facilities and purchase of land and new equipment in consolidated businesses. **g** Fiscal year ended Sept. 30. **h** Fiscal year ended June 30. **i** Fiscal year ended Nov. 30. **j** Fiscal year ended Oct. 31. **na** = not available. **def** = deficit.

Chemical capital spending continues to rise

Capital spending by U.S. chemical producers continued to rise in 1990. In a year when earnings and profitability were both down, the 25 major chemical firms that C&EN tracks still increased their capital spending budgets a healthy 12% over already respectable 1989 spending levels.

The 1990 hike is much lower than the 23% increase in capital spending that these companies posted in 1989 or the 29% hike of 1988. Nevertheless, it's a good deal higher than the 4% annual compound growth rate during the past 10 years for the companies whose plant outlays are tabulated by C&EN.

As a percentage of sales, capital spending by the 25 companies continued to rise in 1990, reaching 10.6% and making 1990 the first year since 1982 when this figure topped 10%. Capital spending as a percentage of sales in 1989 was 9.9%. For much of the mid-1980s this value hovered around 8%.

The Department of Commerce's much wider survey of the chemical industry found a similar rise in capital expenditures in 1990. Their measure was up 11%. And, as of the first quarter of 1991, chemical companies planned to continue increasing capital spending in 1991, according to Commerce Department data. Plans for 1991 called for a 5% increase in capital outlays to reach $21.6 billion this year.

A separate survey by the Conference Board, meanwhile, shows that the backlog of unspent funds ticketed for plant expansions by chemical

INDUSTRY CAPITAL SPENDING: Holding steady for 1991 following three years of big gains

$ Billions	1991[a]	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981
Chemicals	$ 21.63	$ 20.54	$ 18.47	$ 19.25	$ 16.42	$ 16.81	$ 16.44	$ 15.32	$ 12.96	$ 12.66	$ 13.11
Iron and steel	7.20	7.81	7.87	6.16	4.69	3.32	4.12	3.54	3.25	3.78	3.48
Nonferrous metals	2.88	2.88	2.64	2.77	2.16	1.93	1.88	2.13	1.74	1.90	2.51
Paper	13.10	16.72	15.58	11.23	9.01	8.77	8.59	7.21	5.92	5.60	6.11
Petroleum	38.45	34.46	30.08	19.93	17.12	17.92	26.71	25.53	23.14	26.39	25.98
Rubber	3.44	3.48	3.79	3.86	3.52	3.89	3.86	3.11	2.46	2.16	2.15
Stone, clay, glass	3.19	3.31	4.00	3.59	3.37	3.14	3.40	3.09	2.77	2.90	3.41
All manufacturing	193.39	192.76	183.80	165.70	145.90	142.69	153.48	138.82	116.20	120.68	126.54

a Estimate. **Source:** Department of Commerce

Chemicals and petroleum sectors lead industry in unspent capital appropriations

$ Billions	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980
Chemicals	$ 12.6	$ 11.9	$ 10.6	$ 7.0	$ 6.2	$ 8.0	$ 7.8	$ 7.5	$ 7.4	$ 9.4	$ 9.8
Iron and steel	2.4	2.9	2.7	1.4	0.5	1.1	2.1	2.2	2.7	5.4	3.9
Nonferrous metals	2.1	2.3	1.6	1.7	1.6	2.3	2.5	3.2	3.2	3.7	3.7
Paper	14.6	17.4	12.3	6.3	4.4	4.3	5.9	4.0	5.1	5.1	4.0
Petroleum	23.4	17.1	14.6	15.2	16.7	26.2	24.7	22.3	22.9	29.7	26.7
Rubber	3.9	3.5	2.8	1.7	1.9	3.1	1.6	1.1	1.0	0.9	1.0
Stone, clay, glass	2.5	2.7	2.8	2.4	1.6	2.0	2.2	1.5	1.6	1.9	2.0
All manufacturing	106.3	114.2	101.7	76.8	69.7	95.0	94.4	73.7	70.8	92.7	91.9

Note: Figures are for fourth quarter of each year. **Source:** Conference Board

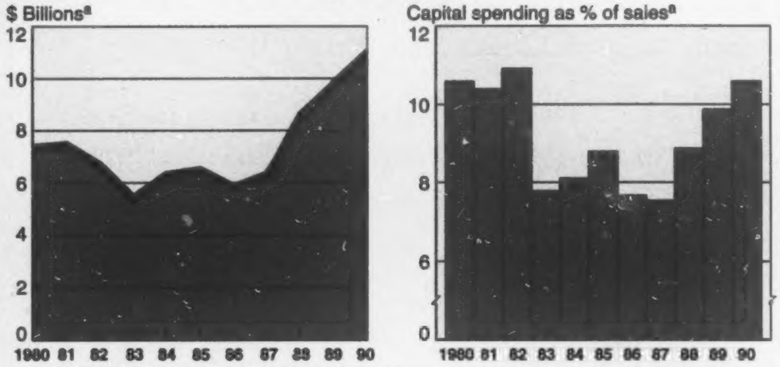
Capital spending by chemical firms abroad continues to rise strongly

$ Billions[a]	1991[b]	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981
Chemicals and allied products	$ 6.6	$ 6.2	$ 5.3	$ 4.7	$ 3.7	$ 3.1	$ 2.7	$ 2.4	$ 2.3	$ 2.8	$ 3.0
Metals, primary and fabricated	1.3	2.1	1.5	1.1	0.8	0.9	0.9	1.0	0.9	0.9	0.8
Petroleum	18.6	1.56	14.4	13.3	9.8	9.6	13.7	14.1	15.9	19.7	15.8
All manufacturing	29.8	27.4	23.4	20.8	17.2	16.4	14.9	13.6	13.6	16.8	19.2

a By majority-owned affiliates of U.S. companies. b Planned. **Source:** Department of Commerce producers was 6% higher at the end of 1990 than a year earlier, rising to nearly $13 billion.

The hectic rate of increase in capital spending abroad by U.S. chemical companies continued in 1990, though Commerce Department data suggest the pace will slow in 1991. Overseas affiliates of U.S. chemical producers increased their outlays 17% in 1990, compared with a 13% rise in 1989. For 1991, they plan only a 6% rise in overseas expenditures.

Chemical capital spending has more than doubled since 1983, and continues to grow faster than sales



a Worldwide data for 25 major chemical producers. **Source:** Company data

CHEMICAL CAPITAL SPENDING: Tops $11 billion in third straight year of strong growth

$ Millions	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980
Air Products	$ 468	$ 414	$ 409	$ 323	$ 367	$ 392	$ 263	$ 246	$ 347	$ 323	$ 364
American Cyanamid	376	398	374	268	263	203	200	165	171	181	196
Cabot[a]	298	233	214	83	80	184	505	80	152	194	137
Chemed	13	14	15	9	9	7	9	5	4	4	4
Crompton & Knowles	16	13	7	4	4	3	3	2	3	7	10
Dow Chemical	2,119	1756	1264	995	890	806	781	630	829	1176	1184
Du Pont[b]	3,142	2563	2029	1674	1587	1515	1319	1276	1300	1420	1297
Ethyl	166	119	151	139	134	90	103	85	92	141	156
B. F. Goodrich	243	240	181	143	144	202	153	115	144	205	184
W. R. Grace	514	485	418	243	199	348	380	353	560	657	658
Great Lakes Chemical	49	40	47	35	18	21	29	20	29	47	21
Hercules	273	293	251	205	257	234	218	168	174	167	229
Loctite	29	24	15	17	11	9	10	9	9	11	14
Lubrizol	77	65	55	42	41	40	30	25	52	75	92
Monsanto	750	607	590	505	520	645	614	560	673	668	781
Nalco Chemical	115	86	62	57	64	60	53	41	56	59	35
Olin	187	142	147	115	128	154	165	123	129	186	172
PPG Industries	415	537	410	426	356	452	315	450	452	376	401
Petrolite	18	19	20	19	25	24	11	9	24	15	17
Quaker Chemical	13	8	5	4	5	6	4	2	2	1	5
Quantum Chemical	459	589	334	154	102	76	116	71	66	44	49
Rohm & Haas	412	385	338	222	179	159	124	72	126	182	93
Stepan	38	34	20	26	14	19	12	10	16	12	9
Union Carbide	744	726	608	452	466	649	670	761	1179	1186	1129
Witco	91	70	72	69	60	76	85	55	54	83	73
TOTAL	**$11,025**	**$9860**	**$8036**	**$6229**	**$5923**	**$6374**	**$6172**	**$5333**	**$6643**	**$7420**	**$7310**
ANNUAL CHANGE	**12%**	**23%**	**29%**	**5%**	**7%**	**3%**	**16%**	**−20%**	**−10%**	**2%**	**25%**

Note: Figures are for worldwide spending on construction, equipment, and land in consolidated businesses. Where possible, acquisition costs and investments in nonconsolidated businesses are excluded. a Includes acquisitions and investments. b Excludes Conoco. **Source:** Company data

2 Finances of the U.S. Chemical Industry

SHIPMENTS: Like all manufacturing, chemical products make modest gains in 1990

$ Billions	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	Annual change 1989–90	Annual change 1980–90
All manufacturing industries	$2860.3	$2781.4	$2611.6	$2390.0	$2260.3	2279.1	$2254.4	$2054.9	$1960.2	$2017.5	$1852.7	3%	4%
Chemicals and allied products	265.7	255.5	240.5	212.7	197.1	197.3	198.2	183.2	170.7	180.5	162.5	4	5
Industrial chemicals[a]	70.4	68.9	67.8	59.5	54.1	59.6	61.5	56.6	53.2	62.7	57.3	2	2
Drugs, soap, and toiletries	87.3	82.0	73.1	67.1	65.8	60.9	57.5	54.4	50.7	46.9	41.9	6	8
Petroleum and coal products	169.6	138.5	124.2	124.5	124.9	179.1	189.0	192.6	208.9	224.1	198.7	22	−2
Rubber and plastic products	90.1	95.8	91.1	80.5	73.4	71.3	69.5	60.3	55.4	53.2	47.3	−6	7
Paper and allied products	131.2	130.4	124.2	110.3	97.9	93.4	94.8	84.6	79.9	80.2	72.8	1	6

a Excluding pigments. **Source:** Department of Commerce

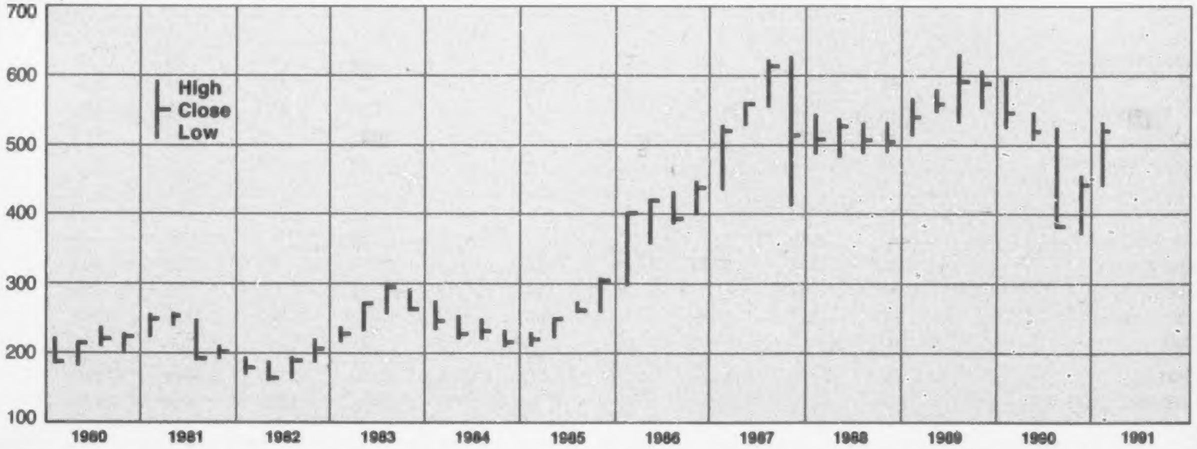
PRICES: Chemical products stagnated while other commodities rose last year

	Annual average											Annual change	
Producer price indexes, 1982 = 100	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1989–90	1980–90
All commodities	116.3	112.2	106.9	102.8	100.2	103.1	103.7	101.3	100.0	98.0	89.8	4%	3%
Industrial commodities	115.8	111.6	106.3	102.6	99.9	103.7	103.3	101.1	100.0	97.4	88.0	4	3
Finished goods	119.2	113.6	108.0	105.4	103.2	104.7	103.7	101.6	100.0	96.1	88.0	5	3
Chemicals and allied products	123.6	123.0	116.3	106.4	102.5	103.7	102.9	100.2	100.0	98.4	89.1	0	3
Industrial chemicals	113.2	114.8	106.8	95.5	91.5	96.0	96.8	97.3	100.0	103.0	91.9	−1	2
Prepared paint	124.8	119.5	112.2	108.1	107.0	105.3	103.7	100.7	100.0	95.0	89.5	4	3
Paint materials	136.3	129.1	115.7	107.3	104.4	109.5	108.2	100.3	100.0	98.5	89.9	6	4
Drugs and pharmaceuticals	170.8	160.0	148.4	139.1	129.9	122.2	114.2	107.7	100.0	92.1	83.1	7	7
Fats and oils, inedible	88.1	95.5	110.9	92.7	80.5	110.6	139.1	106.2	100.0	110.7	111.6	−8	−2
Agricultural chemicals and chemical products	107.4	108.7	104.5	96.4	94.2	96.2	97.4	96.0	100.0	97.5	87.9	−1	2
Plastic resins and materials	124.1	133.4	132.4	110.3	104.4	107.5	108.9	102.4	100.0	102.0	98.5	−7	2
Other chemicals and allied products	118.9	117.3	111.9	107.0	105.8	105.2	102.7	101.3	100.0	94.1	83.1	1	4
Rubber and plastic products	113.6	112.6	109.3	103.0	101.9	101.9	102.2	100.8	100.0	96.4	90.1	1	2

Source: Department of Labor

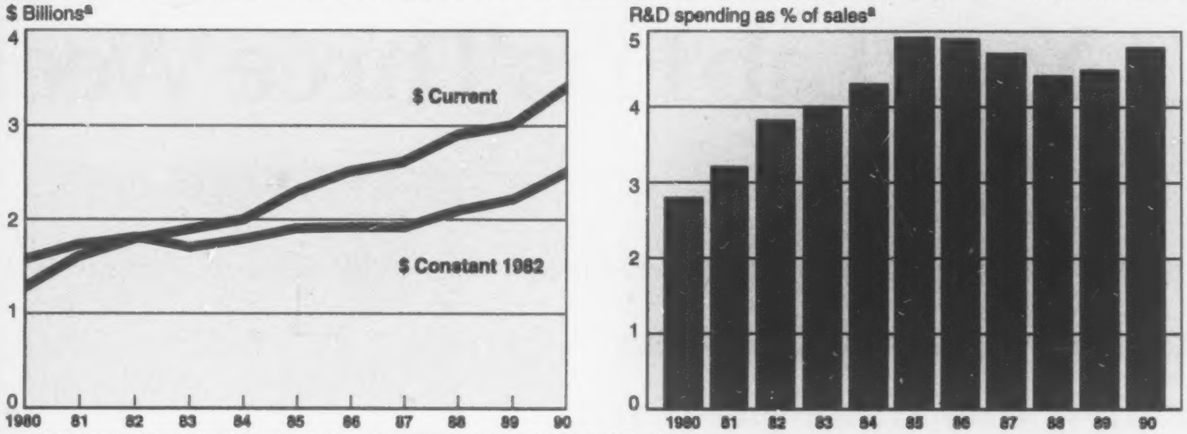
Chemical shares have partially recovered from deep plunge in mid-1990

Stock price index, 1954 = 100[a]



a C&EN stock price index of American Cyanamid, Dow Chemical, W. R. Grace, Hercules, Monsanto, Rohm & Haas, and Union Carbide, weighted according to number of shares outstanding for each company.

R&D spending made healthy rise in 1990 in real terms and as a percentage of company sales



a R&D spending by 15 major chemical producers. **Sources:** Company data, Battelle Columbus Laboratories

R&D SPENDING: Most companies made significant increases in 1990

$ Millions	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980
CHEMICAL COMPANIES											
Air Products[a]	$ 72	$ 71	$ 72	$ 57	$ 61	$ 51	$ 44	$ 40	$ 37	$ 32	$ 30
American Cyanamid	460	406	365	314	278	251	232	208	185	166	148
Dow Chemical	1136	873	772	670	605	547	507	492	460	404	314
Ethyl	65[b]	61[b]	59[b]	50	47	47	40	39	39	37	34
W. R. Grace	148	125	119	107	94	92	81	73	64	57	45
Hercules	92	79	74	74	71	76	72	74	74	65	57
International Flavors	57	52	50	45	39	34	32	32	31	30	29
Lubrizol	74	70	65	62	51	44	33	37	36	33	28
Monsanto	612	598	648	615	596	470	370	290	264	233	208
Nalco	45	41	37	35	33	32	32	30	33	30	28
Olin	66	66	58	62	56	53	52	49	45	38	31
Petrolite	12	12	12	12	12	12	12	13	10	8	7
PPG Industries	218	233	232	227	204	176	150	127	127	119	103
Rohm & Haas	178	175	156	142	133	124	109	100	92	77	67
Union Carbide	191	181	159	159	148	275	265	245	240	207	166
TOTAL	**$3426**	**$3043**	**$2867**	**$2631**	**$2428**	**$2284**	**$2031**	**$1849**	**$1737**	**$1536**	**$1295**
ANNUAL CHANGE	**13%**	**6%**	**9%**	**8%**	**6%**	**12%**	**10%**	**6%**	**13%**	**19%**	**17%**
PHARMACEUTICAL & DIVERSIFIED COMPANIES											
Allied-Signal[c]	$ 721	$ 603	$ 647	$ 667	$ 734	$ 470	$ 389	$ 383	$ 177	$ 152	$ 105
Du Pont	1428	1387	1319	1223	1156	1144	1097	966	879	718	591
Eastman Kodak	1329	1253	1147	992	1059	976	838	746	710	615	520
Eli Lilly	703	605	512	466	427	370	341	294	267	235	201
FMC	158	150	144	132	146	149	121	102	105	94	81
Merck & Co.	854	751	669	566	480	426	393	356	320	274	234
Morton International[c,d]	48	38	35	31	29	34	28	21	7	6	6
Pfizer	640	531	473	401	336	287	255	230	199	179	162
Upjohn	427	407	380	356	314	284	247	218	185	162	139
TOTAL	**$6308**	**$5725**	**$5326**	**$4834**	**$4681**	**$4140**	**$3709**	**$3316**	**$2849**	**$2435**	**$2039**
ANNUAL CHANGE	**10%**	**7%**	**10%**	**3%**	**13%**	**12%**	**12%**	**16%**	**17%**	**19%**	**17%**

Note: Prior years not restated to reflect company revisions. a For fiscal year ending Sept. 30. b Adjusted to reflect spin-off of Tredegar Industries. c Includes all company-financed R&D but excludes contract R&D. d Fiscal year ends June 30; data for Morton Thiokol prior to 1985. **Source:** Company data

INDUSTRY BALANCE SHEET: Liabilities, particularly long-term debt, show greatest rise

Industrial chemicals and synthetics

Assets	1990	1989	Change
	($ billions)		
Current assets			
Cash	$ 1.20	$ 1.66	−28%
Short-term securities	1.10	1.41	−22
Receivables	18.45	16.77	10
Inventories	14.51	13.91	4
Other current assets	4.57	3.87	18
Total	**39.82**	**37.62**	**6**
Fixed assets			
Depreciable fixed assets	99.20	91.06	9
Land and mineral rights	8.16	2.96	146
Less: accumulated depreciation and depletion	51.01	47.42	8
Net fixed assets	**56.35**	**46.61**	**21**
Other assets, including investments and intangibles	**39.82**	**36.53**	**9**
TOTAL ASSETS	**$135.99**	**$120.76**	**13%**

Source: Bureau of the Census

Liabilities and stockholders' equity	1990	1989	Change
	($ billions)		
Current liabilities			
Short-term debt	$ 6.02	$ 4.85	24%
Accounts payable	9.24	8.49	9
Accrued income taxes	1.38	1.27	9
Current portion of long-term debt	1.46	1.87	−22
Other current liabilities	11.49	10.06	14
Total	**29.59**	**26.54**	**11**
Long-term debt	**33.05**	**27.23**	**21**
Other liabilities, including deferred taxes and minority interest	**14.92**	**12.26**	**22**
TOTAL LIABILITIES	**77.55**	**66.02**	**17**
Stockholders' equity			
Capital stock and other capital	19.10	16.37	17
Retained earnings	39.34	38.37	3
TOTAL STOCKHOLDERS' EQUITY	**58.44**	**54.74**	**7**
TOTAL LIABILITIES AND STOCKHOLDERS' EQUITY	**$135.99**	**$120.76**	**13%**

DEBT RATIOS: High levels of recent years show no signs of abatement

$ Billions	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980
INDUSTRIAL CHEMICALS AND SYNTHETICS											
Long-term debt	$ 33.1	$ 29.4	$ 28.5	$ 28.3	$ 20.8	$ 19.2	$ 18.1	$ 19.4	$ 22.0	$ 21.4	$ 16.8
Stockholders' equity	$ 58.4	$ 56.6	$ 51.7	$ 45.3	$ 41.6	$ 40.8	$ 46.5	$ 45.3	$ 45.9	$ 42.5	$ 39.8
Debt ratio[a]	36.2%	34.2%	35.6%	38.4%	33.4%	32.0%	28.0%	30.0%	32.4%	33.5%	29.6%
CHEMICALS AND ALLIED PRODUCTS											
Long-term debt	$ 74.5	$ 64.2	$ 58.9	$ 53.6	$ 46.8	$ 38.2	$ 33.8	$ 36.2	$ 38.2	$ 36.9	$ 28.3
Stockholders' equity	$ 138.6	$ 127.1	$120.5	$106.9	$100.8	$100.3	$100.3	$ 97.2	$ 95.3	$ 89.9	$ 79.5
Debt ratio[a]	35.0%	33.5%	32.8%	33.4%	31.7%	27.6%	25.2%	27.2%	28.6%	29.1%	26.3%
ALL MANUFACTURING											
Long-term debt	$ 623.0	$ 594.9	$535.4	$451.7	$407.5	$367.0	$324.2	$286.6	$293.1	$266.5	$236.2
Stockholders' equity	$1051.2	$1006.3	$979.9	$912.8	$878.1	$870.7	$883.6	$837.6	$783.0	$762.3	$699.7
Debt ratio[a]	37.2%	37.2%	35.3%	33.1%	31.7%	29.6%	26.8%	25.5%	27.2%	25.9%	25.2%

Note: Because of the changes in accounting rules and industry classifications, numbers over the entire range of years are not strictly comparable. [a] Long-term debt as a percentage of long-term debt plus stockholders' equity. **Source:** Bureau of the Census

CASH FLOW: With profits down, companies used working capital to finance efforts last year

$ Millions, % of total	1990		1989		1988		1987		1986	
SOURCES OF FUNDS										
Net income	$ 6,007	23.8%	$ 7,621	29.2%	$ 7,698	39.2%	$ 5,749	29.8%	$ 3,395	13.4%
Depreciation and depletion	6,596	26.2	6,108	23.4	5,602	28.6	5,311	27.6	5,157	20.3
Deferred taxes	660	2.6	156	0.6	302	1.5	304	1.6	555	2.2
Other internal sources	4,248	16.9	3,355	12.8	2,164	11.0	4,257	22.1	6,378	25.1
Long-term debt	7,152	28.4	8,125	31.1	3,619	18.4	2,893	15.0	8,732	34.4
Stock	535	2.1	753	2.9	236	1.2	759	3.9	1,199	4.7
TOTAL	**$25,196**	**100.0%**	**$ 26,118**	**100.0%**	**$19,622**	**100.0%**	**$19,273**	**100.0%**	**$25,416**	**100.0%**
APPLICATIONS OF FUNDS										
Dividends	$ 2,992	11.9%	$ 2,602	10.0%	$ 2,308	11.8%	$ 2,196	11.4%	$ 1,994	7.8%
Capital expenditures	11,614	46.1	10,017	38.4	9,125	46.5	6,525	33.9	6,076	23.9
Additions to working capital	901	3.6	−1,714	−6.6	756	3.9	2,868	14.9	−437	−1.7
Reduction of long-term debt	3,701	14.7	5,529	21.2	3,107	15.8	2,649	13.7	7,801	30.7
Other applications	5,988	23.7	9,685	37.1	4,326	22.0	5,035	26.1	9,982	39.3
TOTAL	**$25,196**	**100.0%**	**$ 26,118**	**100.0%**	**$19,622**	**100.0%**	**$19,273**	**100.0%**	**$25,416**	**100.0%**

Note: Data are totals for 12 major chemical producers: American Cyanamid, Dow Chemical, Du Pont, Ethyl (excludes insurance business), B. F. Goodrich, W. R. Grace, Hercules, Monsanto, Olin, Quantum Chemical, Rohm & Haas, and Union Carbide. **Sources:** Company annual reports

Explanation of company results table headings

Year. Data are for calendar year unless otherwise indicated.

Net sales. Gross sales, less discounts, allowances, and returns; generally excludes excise taxes and other operating income or revenues.

Net income. Net sales and other income, less operating costs, nonoperating charges, depreciation, depletion, interest expense, deferred charges, minority interest in income, and taxes. Nonrecurring or extraordinary credits and charges have been excluded in most cases, but are footnoted.

Total assets. Sum at year's end of current assets, investments, prepaid expenses, net plant and equipment, and other tangible assets. Excludes insofar as possible intangible assets including goodwill, value of patents, and the like.

Current ratio. The ratio of current assets (cash, marketable securities, receivables, inventories, and prepaid expenses) to total current liabilities.

Net plant and equipment. Value at year's end of fixed assets, less accumulated depreciation, amortization, and depletion.

Capital expenditures. Total spending during the year for new fixed assets, such as plant, equipment, and land, and for replacement and modernization of facilities.

Stockholders' equity. Equity at year's end of preferred and common stockholders, including value of capital stock, capital and earned surplus, and surplus reserves, as well as contingency and miscellaneous reserves for which no definite purpose is stated. Intangible assets are deducted insofar as possible.

Net income. (breakdown). **Percent of sales:** net income divided by net sales. **Percent of net worth:** net income divided by tangible net worth. **Dollars per share:** net income, less preferred dividends, divided by the number of shares of common stock outstanding. All figures are adjusted for stock splits, but no adjustment has been made for earlier years as a result of stock dividends or for dilution that might result from the conversion of preferred stock or debt to common stock or the exercise of stock options outstanding.

Dividends per share. Cash dividends paid (or declared) on each share of common stock; excludes the value of stock dividends, which are indicated by a footnote.

Dividend yield. Dividends per share divided by the average of the high and low prices of the common stock during the calendar year.

Stock price range. High-low market prices of common stock during the year, adjusted for stock splits but not for stock dividends.

Price-earnings ratio. Average of the high and low prices of the common stock during the calendar year divided by net income per share.

COMPANY RESULTS: Almost half of chemical and all drug companies boosted earnings last year

Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Stockholders' equity	NET INCOME % of sales	NET INCOME % of stockholders' equity	NET INCOME $ per share	Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
(Money figures in thousands of dollars unless otherwise indicated)														
CHEMICALS														
Air Products & Chemicals														
1990[a]	$2,894,700	$229,900	$3,844,800	1.2	$2,485,100	$467,500	$1,633,700	7.9%	14.1%	$4.15	$1.38	2.7%	$61–43	12.5
1989[a]	2,641,823	222,137	3,313,343	1.4	2,217,594	413,735	1,392,534	8.4	16.0	4.04	1.26	2.9	48¾–37¾	10.7
1988[a]	2,431,866	213,747	2,962,295	1.1	2,061,642	386,907	1,235,027	8.8	17.3	3.90	1.10	2.7	53⅛–29	10.6
1987[a]	2,132,176	159,688[b]	2,695,625	1.2	1,920,520	312,712	1,140,512	7.5	14.0	2.83[b]	0.90	2.0	53⅞–35⅛	15.6
American Cyanamid Co.														
1990	$4,570,200	$107,800[c]	$4,864,000	1.5	$1,906,000	$375,500	$2,334,700	2.4%	4.6%	$1.15[c]	$1.35	2.2%	$61½–42	5.3
1989	4,825,000	292,000	4,719,800	1.4	1,757,000	397,600	2,070,000	6.1	14.1	3.12	1.31	2.5	60⅜–45⅝	17.0
1988	4,592,000	305,600	4,332,200	1.4	1,556,800	373,800	1,801,100	6.7	17.0	3.41	1.16	2.4	56–41⅞	14.4
1987	4,166,100	264,000[d]	3,878,400	1.5	1,391,900	268,100	1,622,400	6.3	16.3	2.89[d]	1.025	2.4	57–29	14.9
Arco Chemical Co.														
1990	$2,950,000	$351,000	$3,739,000	2.6	$1,768,000	$539,000	$1,758,000	11.9%	20.0%	$3.66	$2.50	6.6%	$44¼–29¾	10.1
1989	2,663,000	405,000	2,655,000	2.0	1,263,000	262,000	1,591,000	15.5	25.5	4.22	2.125	6.1	40⅜–28¾	8.2
1988	2,700,000	494,000	2,548,000	1.8	1,078,000	214,000	1,375,000	18.3	35.9	5.00	0.85	2.8	38–23¼	6.1
1987[e]	1,952,000	257,000	2,534,000	1.3	984,000	290,000	1,116,000	13.2	23.0	2.58[f]	0.20	0.7	38¾–17	10.8
Betz Laboratories														
1990	$596,805	$65,474	$420,589	2.3	$233,451	$57,540	$213,938	11.0%	30.6%	$2.12	$1.01	2.7%	$43¼–30¾	17.5
1989	516,669	55,860	358,743	2.6	201,464	52,952	172,971	10.8	32.3	1.76	0.89	3.2	31⅛–23⅝	15.5
1988	447,580	48,385	307,862	1.9	174,970	43,505	219,901	10.8	22.0	3.15	1.60	3.4	52½–41¼	14.9
1987	385,868	40,634	275,664	1.7	153,200	25,428	193,959	10.5	20.9	2.59	1.46	3.1	58¼–35	18.0

a Fiscal year ends Sept. 30. b Excludes extraordinary net loss on extinguishment of debt of $4.1 million ($0.07 per share). c From continuing operations: excludes net income from discontinued operations of $245 million ($2.56 per share) but includes special net costs of $206.2 million ($2.15 per share) to curtail and consolidate product lines, reduce the carrying value of certain assets, increase environmental remediation costs, and reduce employees. d From continuing operations: excludes net income from discontinued operations of $11.6 million ($0.13 per share) but includes gain on sale of fragrance and skin care business, before taxes, of $12.0 million ($0.13 per share). e Arco Chemical, previously a subsidiary of Atlantic Richfield Co., became an independent, publicly owned company on Oct. 5, 1987. f Pro forma.

2 Finances of the U.S. Chemical Industry

								NET INCOME						
Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Stockholders' equity	% of sales	% of stockholders' equity	$ per share	Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
						(Money figures in thousands of dollars unless otherwise indicated)								
Borden Chemicals & Plastics Ltd. Partnership														
1990	$420,631	$45,296	$544,204	1.6	$395,762	$22,084	$314,558	10.8%	14.4%	$1.22[a]	$1.95[a]	19.0%	$12¾–7¾[a]	8.4
1989	465,923	69,495	549,628	1.9	417,186	28,157	341,707	14.9	20.3	1.87[a]	2.45[a]	14.4	24–10[a]	9.1
1988	552,975	121,014	604,822	1.7	429,280	16,877	363,271	21.9	33.3	3.26[a]	3.02[a]	19.5	20⅛–10⅞[a]	4.8
1987[b]	35,894	4,781	560,319	1.7	449,258	3,485	354,534	13.3	—	0.13[a]	0.11[a]	1.0	12–9¾[a]	83.7
Cabot Corp.														
1990[c]	$1,684,658	$71,030	$1,627,435	1.3	$878,651	$174,435	$466,155	4.2%	15.2%	$2.73	$1.04	3.3%	$37½–25	11.4
1989[c]	1,936,912	(6,509)[d,e]	1,400,550	1.4	743,179	192,302	472,333	—	—	(0.40)[d,e]	1.01	2.5	45–34⅞	—
1988[c]	1,676,588	61,175[f]	1,530,186	1.3	838,909	169,957	594,295	3.6	10.3	2.27[f]	0.92	2.5	48⅜–25½	16.3
1987[c]	1,424,041	39,235[g]	1,447,001	1.2	794,470	81,087	574,610	2.8	6.8	1.42[g]	0.92	2.8	45⅛–25½	24.9
Chemed Corp.														
1990	$599,379	$16,554	$272,857	1.5	$65,996	$12,994	$57,843	2.8%	28.6%	$1.60	$1.96	7.1%	$36¾–18⅛	19.7
1989	591,824	26,182	279,181	1.7	65,814	14,116	64,634	4.4	40.5	2.61	1.84	5.2	38⅝–32½	13.6
1988	500,647	20,649[h]	268,496	1.7	61,102	14,641	57,061	4.1	36.2	2.23[h]	1.72	5.1	38–29¾	15.2
1987	391,004	20,362	220,549	1.5	46,545	8,893	69,944	5.2	29.1	2.28	1.60	4.5	44⅛–26⅝	15.5
Crompton & Knowles Corp.														
1990	$390,032	$30,010	$252,177	1.8	$76,709	$16,374	$87,098	7.7%	34.5%	$1.22	$0.39	2.1%	$23⅛–13⅝	15.0
1989	355,817	24,501	190,330	1.8	50,847	13,407	71,381	6.9	34.3	1.00	0.29	2.5	15¾–7½	11.8
1988	289,787	16,845[i]	177,204	1.5	43,685	7,050	53,483	5.8	31.5	0.71[i]	0.21	3.1	9–5	9.8
1987	237,469	11,750	127,689	2.2	29,085	3,632	68,265	4.9	17.2	0.49	0.17	2.8	7⅝–4½	12.4
Dexter Corp.														
1990	$907,946	$42,150	$696,978	2.5	$272,147	$43,910	$278,293	4.6%	15.1%	$1.74	$0.88	4.1%	$24½–18	12.2
1989	848,724	42,977	611,277	2.3	252,895	33,119	242,068	5.1	17.8	1.73	0.82	3.0	34¾–20⅛	15.9
1988	827,266	39,889[j]	540,960	2.2	186,894	26,145	221,795	4.8	18.0	1.61[j]	0.80	3.3	28¾–20¼	15.2
1987	782,781	42,785	517,296	2.3	183,972	23,619	205,269	5.5	20.8	1.72	0.60	2.4	32⅝–17	14.4
Dow Chemical Co.														
1990	$19,773,000	$1,384,000	$19,764,000	1.4	$8,249,000	$2,119,000	$4,539,000	7.0%	30.5%	$5.10	$2.60	4.6%	$75¾–37	11.1
1989	17,600,000	2,487,000	18,169,000	1.1	7,642,000	1,764,000	3,960,000	14.1	62.8	9.20	2.18	3.4	72¼–55½	6.9
1988	16,682,000	2,410,000[k]	15,548,000	1.9	6,576,000	1,267,000	6,564,000	14.4	36.7	8.55[k]	1.63	2.9	62⅝–51⅛	6.7
1987	13,377,000	1,245,000[l]	13,871,000	1.7	5,551,000	995,000	5,284,000	9.3	23.6	4.33[l]	1.40	2.5	73–39⅛	13.0
E. I. du Pont de Nemours & Co.														
1990	$40,047,000	$2,310,000	$37,332,000	1.2	$21,102,000	$5,383,000	$15,622,000	5.8%	14.8%	$3.40	$1.62	4.3%	$42⅝–31⅝	10.8
1989	35,534,000	2,480,000	33,829,000	1.2	18,876,000	4,285,000	14,912,000	7.0	16.6	3.53	1.45	4.1	42⅛–28⅝	10.0
1988	32,917,000	2,190,000	30,159,000	1.5	17,221,000	4,001,000	15,020,000	6.7	14.6	3.04	1.23	4.4	30⅞–25¼	9.3
1987	30,468,000	1,786,000	27,604,000	1.5	15,854,000	3,035,000	13,639,000	5.9	13.1	2.46	1.10	3.2	43⅝–25	13.9
Ethyl Corp.														
1990	$2,513,755[m]	$232,189	$6,588,643	2.1	$677,028	$151,822	$946,539	9.2%	24.5%	$1.95	$0.60	2.2%	$33–20½	13.7
1989	2,431,654[m]	219,468[n]	5,507,009	2.3	579,760	119,082	776,785	9.0	28.3	1.83[n]	0.51	2.0	29–21⅛	13.7
1988	2,717,965[m]	231,016	5,107,817	2.5	719,551	151,116	986,289	8.4	23.4	1.91	0.45	2.2	24⅛–17¼	10.8
1987	2,274,702[m]	193,319	4,214,975	2.2	674,075	138,481	852,799	8.5	22.7	1.57	0.40	1.7	32¼–15	15.0
Ferro Corp.														
1990	$1,124,833	$19,419	$672,282	1.6	$255,930	$59,694	$292,221	1.7%	6.6%	$0.83	$0.64	2.7%	$29⅝–17¼	28.1
1989	1,083,573	49,748	655,206	1.8	220,022	49,581	283,144	4.6	17.6	2.30	0.60	1.9	41⅝–22⅝	13.8
1988	1,008,990	46,620	574,943	1.7	197,222	49,308	282,137	4.6	16.5	2.26	0.46	2.3	27⅛–14	9.1
1987	871,086	31,687	521,314	1.7	171,889	30,674	249,039	3.6	12.7	1.53	0.45	2.7	20⅞–11⅝	10.6
First Mississippi Corp.														
1990[o]	$497,539	$4,374	$497,453	1.6	$310,032	$64,600	$175,344	0.9%	2.5%	$0.22	$0.30	1.9%	$19¼–11⅝	70.2
1989[o]	433,469	16,511	472,394	1.7	280,008	107,011	187,145	3.8	8.8	0.81	0.285	1.6	20½–14½	21.6
1988[o]	318,086	32,475	325,339	1.5	166,966	60,381	181,447	10.2	17.9	1.61	0.24	1.7	19⅛–9½	8.9
1987[o]	278,946	18,610	276,636	1.8	152,671	19,527	138,882	6.7	13.4	0.93	0.24	2.6	13⅝–5⅝	10.1
Georgia Gulf Corp.														
1990	$932,104	$95,344	$439,229	1.3	$214,749	$58,111	$(441,904)[p]	10.2%	—	$3.07	—	—	$45⅝–4⅞	7.2
1989	1,104,468	191,990	455,561	2.3	209,080	54,159	305,828	17.4	62.8%	7.58	$1.00	2.1%	59⅞–36	6.3
1988	1,060,612	193,604	437,083	2.0	169,256	25,062	235,839	18.3	82.1	6.75	0.65	2.0	39⅞–24⅝	4.8
1987	707,435	91,736[q]	308,609	1.7	119,984	9,931	142,546	13.0	64.4	3.15[q]	0.20	0.9	34½–9⅞	7.1

a Per partnership preference unit. b Borden Chemicals & Plastics, previously the basic chemicals and polyvinyl chloride operations of Borden Inc., commenced independent operations as a publicly owned limited partnership Nov. 30, 1987. c Fiscal year ends Sept. 30. d Net loss. e From continuing operations: includes pretax loss on restructuring of energy group of $71.7 million but excludes net gain from sale of discontinued operations of $24.6 million ($0.95 per share). f Excludes extraordinary net charge on early retirement of debt of $816,000 ($0.03 per share). g Excludes extraordinary net charge on early retirement of debt of $10.5 million ($0.38 per share). h From continuing operations: excludes net income from discontinued operations, extraordinary net gain on termination of pension plan, and cumulative effect of changes in accounting principles of $3.5 million ($0.37 per share). i From continuing operations: excludes net loss from operations and disposal of maintenance chemicals business of $1.5 million ($0.12 per share). j From continuing oeprations: excludes net loss from discontinued operations of $4.4 million ($0.18 per share). k Excludes net loss on early extinguishment of debt of $12 million ($0.04 per share). l Excludes net loss on early extinguishment of debt of $5 million ($0.02 per share). m Includes insurance revenues. n From continuing operations: excludes income from spun-off aluminum, plastics, and energy businesses of $11.9 million ($0.10 per share). o Fiscal year ends June 30. p Deficit. q Excludes net charge on retirement of debt of $9.9 million ($0.34 per share).

Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Stockholders' equity	NET INCOME % of sales	NET INCOME % of stockholders' equity	NET INCOME $ per share	Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
					(Money figures in thousands of dollars unless otherwise indicated)									
B. F. Goodrich Co.														
1990	$2,419,700	$115,800[a]	$2,198,400	1.4	$1,109,300	$243,000	$1,200,300	4.8%	9.6%	$4.20[a]	$2.12	5.5%	$47⅞–29½	9.2
1989	2,419,700	171,200[b]	2,102,900	2.0	991,500	240,400	1,117,000	7.1	15.3	6.23[b]	2.00	3.7	69–38½	8.6
1988	2,416,700	209,900[c]	1,987,300	1.9	934,400	180,500	1,080,200	8.7	19.4	7.99[c]	1.72	3.5	60¾–37½	6.1
1987	2,168,000	83,900[d]	1,905,800	1.4	898,200	142,600	972,600	3.9	8.6	3.17[d]	1.56	3.4	65–27¾	14.6
W. R. Grace & Co.														
1990	$6,754,000	$202,800	$5,875,900	1.4	$2,462,100	$513,700	$1,561,900	3.0%	13.0%	$2.36	$1.40	5.5%	$33⅝–17	10.7
1989	6,114,600	256,600[e]	5,321,300	1.3	2,220,000	484,600	1,432,600	4.2	17.9	3.01[e]	1.40	4.4	39⅛–25⅛	10.7
1988	5,786,100	192,000[f]	5,095,200	1.3	2,028,300	416,100	1,336,000	3.3	14.4	2.26[f]	1.40	5.2	29⅞–23½	11.8
1987	4,515,400	141,900[g]	4,361,500	1.4	1,701,000	242,500	1,351,200	3.1	10.5	1.67[g]	1.40	5.0	37⅜–19⅛	16.9
Great Lakes Chemical Corp.														
1990	$1,066,298	$140,849	$1,200,595	2.0	$363,798	$48,565	$538,457	13.2%	26.2%	$4.01	$0.46	0.9%	$65⅞–40¾	13.3
1989	792,327	122,918	934,802	2.0	275,864	40,466	428,263	15.5	28.7	3.52	0.38	1.0	48–28⅛	10.8
1988	557,770	103,288	612,242	1.7	234,405	47,017	430,629	18.5	24.0	2.97	0.34	1.2	33–24¼	9.7
1987	478,386	55,536	523,365	1.6	218,403	35,186	338,880	11.6	16.4	1.67	0.30	1.1	38½–18	16.9
Hercules														
1990	$3,199,932	$95,993	$3,699,644	1.8	$1,449,912	$272,591	$1,941,989	3.0%	4.9%	$2.04	$2.24	6.7%	$41½–25⅝	16.5
1989	3,091,669	(96,359)[h,i]	3,653,163	1.7	1,416,475	292,554	1,897,206	—	—	(2.09)[h,i]	2.24	4.9	52¼–38⅝	—
1988	2,802,072	120,435	3,325,294	2.6	1,164,102	251,043	2,044,533	4.3	5.9	2.55	2.00	4.1	54–42⅝	18.9
1987	2,693,003	208,000[j]	3,492,077	3.6	1,075,389	205,037	2,189,867	7.7	9.5	4.02[j]	1.84	3.2	73½–40	14.1
Imcera														
1990[k]	$1,424,600	$58,900[l]	$1,750,800	1.6	$585,800	$85,700	$444,700	4.1%	13.2%	$2.53[l]	$1.00	1.9%	$62⅛–42⅝	20.7
1989[k]	982,900	110,300[m]	1,753,000	3.2	480,200	82,200	669,600	11.2	16.5	4.20[m]	1.00	2.4	47⅜–37¼	10.1
1988[k]	1,470,600	103,900[n]	1,588,900	2.0	445,800	69,100	822,800	7.1	12.6	3.30[n]	1.00	2.5	53–28	12.7
1987[k]	1,637,500	14,600[o]	2,242,400	1.4	2,292,500	62,500	877,200	0.9	1.7	0.08[o]	1.00	2.9	44½–25	434.4
IMC Fertilizer Group														
1990[k]	$1,105,700	$82,600	$1,584,700	1.2	$1,144,100	$94,300	$819,700	7.5%	10.1%	$3.13	$1.08	3.0%	$39¾–31⅛	11.3
1989[k]	1,221,700	137,300	1,677,900	1.4	1,144,100	55,300	765,300	11.2	17.9	5.27	1.02	2.5	49¾–32½	7.8
1988[k,p]	1,085,600	111,700	1,472,100	1.6	780,000	26,300	676,100	10.3	16.5	3.88	0.37	1.1	45⅛–22½	8.7
1987[k]	876,200	26,600	1,332,200	1.7	841,600	110,400	1,004,300	3.0	2.6	0.10	—	—	—	—
International Flavors & Fragrances														
1990	$962,810	$156,681	$1,129,395	5.4	$266,860	$42,931	$898,193	16.3%	17.4%	$4.11	$2.16	3.3%	$75⅛–54⅝	15.8
1989	869,519	138,565	969,649	5.1	236,505	34,178	764,913	15.9	18.1	3.65	1.92	3.0	77½–48½	17.3
1988	839,545	128,684	882,333	5.0	228,152	40,812	695,433	15.3	18.5	3.40	1.60	3.3	54½–43⅛	14.4
1987	745,861	107,017	874,554	4.2	219,305	36,946	659,908	14.3	16.2	2.83	1.24	2.6	57¾–37¼	16.8
Lawter International														
1990	$150,005	$23,420	$153,500	4.2	$28,612	$6,198	$105,090	15.6%	22.3%	$0.73	$0.39	3.9%	$11⅜–8⅝	13.7
1989	136,006	19,468	133,968	3.9	24,412	3,073	87,752	14.3	22.2	0.61	0.39	4.1	10–8½	15.6
1988	125,818	20,851	125,210	3.7	24,546	4,524	79,521	16.6	26.2	0.88	0.52	4.2	14⅛–10¾	14.1
1987	112,018	16,701	109,917	4.3	22,603	1,528	69,458	14.9	24.0	0.71	0.42	3.5	15⅝–8½	17.0
Loctite Corp.														
1990[k]	$509,737	$61,372	$411,687	2.8	$91,256	$26,917	$258,635	12.0%	23.7%	$3.39	$1.14	2.2%	$61–40⅞	15.0
1989[k]	456,498	54,476	344,206	2.8	70,143	15,983	211,805	11.9	25.7	3.03	0.90	2.5	45¼–28⅛	12.0
1988[k]	416,880	41,850	328,833	2.4	73,008	14,466	187,100	10.0	22.4	2.32	0.61	2.1	39–19	12.5
1987[k]	337,802	30,655	289,367	1.9	70,802	15,470	167,561	9.1	18.3	1.89	0.47	1.8	31⅝–19½	15.1
Lubrizol Corp.														
1990	$1,444,758	$127,146[q]	$1,097,091	2.5	$353,551	$77,407	$718,706	8.8%	17.7%	$3.55[q]	$1.46	3.6%	$49–33	11.5
1989	1,220,386	93,980	960,184	2.9	316,493	64,721	663,264	7.7	14.2	2.52	1.38	3.5	45⅛–34⅛	15.7
1988	1,117,493	131,206[r]	970,671	3.0	298,670	54,611	664,308	11.7	19.8	3.40[r]	1.30	3.6	42⅝–30	10.6
1987	1,013,430	81,335	939,378	3.0	297,573	42,040	621,633	8.0	13.1	2.06	1.22	3.6	41¾–25¼	16.3

a From continuing operations: excludes income from discontinued operations of $20.5 million ($0.25 per share). **b** From continuing operations: excludes net income from discontinued operations of $1.2 million ($0.04 per share). **c** From continuing operations: excludes net loss from discontinued operations of $12.1 million ($0.45 per share) and net gain from cumulative effect of change in accounting for income taxes of $2.7 million ($0.11 per share). **d** From continuing operations: excludes net loss from discontinued operations of $4.7 million ($0.20 per share) and extraordinary net income of $25.8 million ($1.09 per share). **e** From continuing operations: excludes net loss from discontinued operations of $3.4 million ($0.04 per share). **f** From continuing operations: excludes net income from discontinued operations and net gain from cumulative effect of accounting change of $41.6 million ($0.49 per share). **g** From continuing operations: excludes net income from discontinued operations of $18.6 million ($0.22 per share) and tax benefit of operating loss carry-forward of $12.6 million ($0.14 per share). **h** Net loss. **i** Excludes net gain from cumulative effect of accounting changes of $15.0 million ($0.33 per share). **j** Excludes net gain on disposal of Himont and other net gains and charges of $613.7 million ($10.72 per share). **k** Fiscal year ends June 30. **l** From continuing operations: excludes gain on sale of fragrance business, after taxes, of $5.2 million ($0.25 per share) and charges for environmental and litigation costs related to previously sold operations of $7.6 million ($0.36 per share). **m** From continuing operations: excludes net gain from discontinued operations of $6.7 million ($0.29 per share). **n** From continuing operations: excludes net loss on disposal of discontinued operations of $5.0 million ($0.19 per share) and extraordinary credit of $16.2 million ($0.55 per share). **o** From continuing operations: excludes net income on disposal of discontinued operations of $11.3 million ($0.41 per share) and extraordinary net charge of $4.8 million ($0.18 per share). **p** IMC Fertilizer Group, previously the fertilizer business group of International Minerals & Chemical Corp., became an independent, privately owned company on Feb. 2, 1988. **q** From continuing operations: excludes gain, after taxes, on sale of Genentech stock of $62.9 million ($1.79 per share) but includes charge for write-off of $9.7 million in inventories and receivables due from a former affiliate. **r** Includes credit for patent litigation settlement, before taxes, of $81.2 million but excludes net credit for cumulative effect of change in accounting for income taxes of $8.8 million ($0.22 per share).

2 Finances of the U.S. Chemical Industry

(Money figures in thousands of dollars unless otherwise indicated)

Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Stockholders' equity	NET INCOME % of sales	NET INCOME % of stockholders' equity	NET INCOME $ per share	Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
Monsanto Co.														
1990	$8,995,000	$546,000[a]	$7,811,000	1.6	$3,492,000	$750,000	$2,664,000	6.1%	20.5%	$4.23[a]	$1.88	3.8%	$60⅛–38¾	11.7
1989	8,681,000	679,000[b]	6,922,000	1.7	3,173,000	607,000	2,259,000	7.8	30.1	5.02[b]	1.65	3.2	62⅛–40¼	10.2
1988	8,293,000	591,000	6,671,100	1.3	3,146,000	590,000	2,010,000	7.1	29.4	4.14	1.475	3.6	46⅛–36¾	10.0
1987	7,639,000	436,000[c]	6,502,000	1.4	3,076,000	505,000	1,948,000	5.7	22.4	2.82[c]	1.375	3.5	50⅛–28½	14.0
Morton International														
1990[d]	$1,638,700	$134,800	$1,448,000	1.8	$646,200	$113,300	$642,400	8.2%	21.0%	$2.80	$0.86	2.3%	$44¾–31½	13.6
1989[d]	1,406,600	97,100	1,169,600	1.8	553,400	131,900	706,000	6.9	13.8	2.03	—	—	41⅞–37½	18.1
1988[d]	1,248,300	116,400[e]	994,800	2.0	478,600	97,700	606,000	9.3	19.2	2.43[e]	0.82[f]	2.0[f]	46–35⅝[f]	—
1987[d]	1,093,900	105,000	1,426,400[f]	1.5[f]	655,900[f]	72,500	700,400[f]	9.6	—	2.21	0.745[f]	1.7[f]	54¾–31[f]	—
NL Industries														
1990	$906,589	$93,506[g]	$1,966,695	2.2	$577,114	$195,304	$38,568	10.3%	242.4%	$1.42[g]	$0.60	3.5%	$24¾–9¼	12.0
1989	1,000,883	170,274[h]	1,512,315	0.9	380,465	83,386	137,310	17.0	124.0	2.57[h]	0.60	2.6	28–18¾	9.1
1988[i]	1,007,036	134,236[j]	836,941	1.4	344,020	70,624	150,951	13.3	88.9	2.02[j]	0.20[k]	3.1	7¾–5¼	—
1987[i]	859,267	87,866[l]	1,092,483	1.5	315,907	73,318	406,220	10.2	21.6	1.31[l]	0.20[k]	2.6	11–4¼	—
Nalco Chemical Co.														
1990	$1,212,258	$131,077	$991,833	2.3	$419,269	$114,919	$410,395	10.8%	31.9%	$1.71	$0.76	2.9%	$30⅝–22	15.4
1989	1,070,754	119,909	892,006	2.3	350,886	86,435	397,207	11.2	30.2	3.01	1.36	3.2	49⅞–34½	14.3
1988	994,150	105,971	794,899	2.0	311,200	61,578	433,550	10.7	24.4	2.70	1.29	3.6	39⅞–31¼	13.2
1987	841,876	80,254	696,360	1.7	304,084	57,232	396,297	9.5	20.3	2.03	1.20	3.5	45½–24	17.1
Olin Corp.														
1990	$2,592,000	$84,000	$1,760,000	1.4	$829,000	$187,000	$609,000	3.2%	13.8%	$4.03	$1.70	3.4%	$60–40	12.4
1989	2,509,000	124,000	1,794,000	1.3	761,000	142,000	555,000	4.9	22.3	6.02	1.95	3.3	68¼–49⅝	10.2
1988	2,308,000	98,000	1,799,000	1.3	801,000	147,000	542,000	4.2	18.1	4.63	1.70	3.4	60–40	10.8
1987	1,930,000	78,000	1,583,000	1.7	727,000	115,000	598,000	4.0	13.0	3.38	1.60	3.6	56¼–32⅝	13.1
Quantum Chemical Corp.														
1990	$2,656,100	$21,200	$3,139,500	2.0	$2,020,200	$458,400	$(183,500)[m]	0.8%	—	$0.79	—	—	$31⅝–6⅛	12.7
1989	2,671,000	114,100[n]	2,910,300	1.7	1,759,300	583,300	(265,800)[m]	4.3	—	4.45[n]	$2.18[o]	3.3%	107⅛–28½	14.9
1988	2,921,900	360,100[p]	2,881,300	0.7	1,308,600	333,500	(433,400)[m]	12.3	—	13.71[p]	2.40[q]	2.8	108¼–65½	6.3
1987	2,566,800	143,600[r]	2,519,300	1.3	1,380,200	154,200	983,500	5.6	14.6%	4.38[r]	2.20	3.4	88–42½	14.9
Rohm & Haas Co.														
1990	$2,824,000	$207,000[s]	$2,645,000	1.7	$1,390,000	$412,000	$1,176,000	7.3%	17.6%	$3.10[s]	$1.22	4.0%	$37–24¼	9.9
1989	2,661,000	176,000[t]	2,361,000	1.7	1,148,000	385,000	1,217,000	6.6	14.5	2.65[t]	1.16	3.4	37½–31	12.9
1988	2,535,000	230,000	2,148,000	1.7	935,000	338,000	1,113,000	9.1	20.7	3.46	1.02	3.1	37½–28	9.5
1987	2,203,000	195,000[u]	1,882,000	1.9	730,000	222,000	981,000	8.9	19.9	2.85[u]	0.86	2.2	53¼–24	13.6
Sigma-Aldrich Corp.														
1990	$529,103	$71,248	$546,190	3.4	$192,372	$32,535	$368,468	13.5%	19.3%	$1.44	$0.205	0.7%	$35⅝–25⅝	21.1
1989	441,099	63,958	472,424	2.6	176,431	51,703	298,851	14.5	21.4	2.59	0.37	0.7	59½–43¾	19.9
1988	375,282	56,477	359,671	2.5	119,518	35,605	243,906	15.0	23.2	2.29	0.33	0.7	51¼–39¾	19.9
1987	304,858	41,889	285,343	2.9	96,975	20,616	196,012	13.7	21.4	1.70	0.29	0.7	50⅝–30¼	23.8
Stepan Co.														
1990	$389,612	$14,491	$246,992	1.6	$143,342	$38,375	$82,698	3.7%	17.5%	$2.64	$0.58	2.6%	$27¼–16⅝	8.3
1989	346,350	7,840	215,351	1.7	122,509	34,090	70,741	2.3	11.1	1.42	0.53	2.2	29½–17¾	16.6
1988	333,033	13,428	185,601	1.6	104,697	20,442	66,790	4.0	20.1	2.39	0.475	2.1	25⅝–19¾	9.5
1987	288,935	10,959	172,726	1.8	98,994	25,705	59,936	3.8	18.3	1.83	0.415	2.0	26¾–14½	11.2
Sterling Chemicals														
1990[v]	$506,046	$59,083	$352,024	1.4	$216,015	$19,915	$108,240	11.7%	54.6%	$1.07	$1.00	14.4%	$8⅝–5¼	6.5
1989[v]	580,797	103,898	329,040	1.5	216,355	57,592	110,372	17.9	94.1	1.77	0.75	5.9	16¾–6⅞	7.2
1988[v]	698,964	213,845[w]	294,242	1.4	172,881	16,993	90,562	30.6	236.1	3.56[w]	3.17	—	17¾–14⅛	4.5
1987[v]	413,192	51,385[x]	283,375	1.2	169,119	13,174	60,184	12.4	85.4	0.86[x]	—	—	—	—
Union Carbide Corp.														
1990	$7,621,000	$308,000[y]	$8,587,000	1.0	$4,325,000	$744,000	$2,227,000	4.0%	13.8%	$2.19	$1.00	5.1%	$24⅞–14⅛	8.9
1989	8,744,000	573,000	8,483,000	1.1	4,584,000	785,000	2,320,000	6.6	24.7	4.07	1.00	3.6	33¼–22¾	6.9
1988	8,324,000	662,000	8,389,000	1.1	4,416,000	671,000	1,784,000	8.0	37.1	4.88	1.15	5.1	28⅜–17	4.6
1987	6,914,000	232,000	7,820,000	1.3	4,344,000	502,000	1,175,000	3.4	19.7	1.76	1.50	6.2	32½–15½	13.6

a Includes net gain on divestitures of $56 million ($0.43 per share). b Includes net gain on sale of analgesics business of $36 million ($0.27 per share). c Includes net restructuring income of $18 million ($0.12 per share). d Fiscal year ends June 30. e Excludes net charge for cumulative effect of change in accounting for income taxes of $3.8 million ($0.07 per share). f Data for Morton Thiokol, of which Morton International was a part until July 1, 1989. g Excludes extraordinary net loss of $1.1 million ($0.02 per share). h Excludes extraordinary net gain of $2.6 million ($0.04 per share). i Restated to reflect restructuring and spin-off of petroleum services business on Dec. 22, 1988 (except as noted). j From continuing operations: excludes net income from discontinued operations of $21.5 million ($0.32 per share). k Before restructuring. l From continuing operations: excludes net loss from discontinued operations of $107.8 million ($1.64 per share). m Deficit. n From continuing operations: excludes net income and net gain on sale of oleochemical business of $133.3 million ($5.31 per share). o Plus 1% stock dividend. p From continuing operations: excludes net income from discontinued oleochemical business of $22.6 million ($0.86 per share). q Excludes special dividend declared of $50 per share. r From continuing operations: excludes net income from discontinued spirits and wine operations of $108.0 million ($3.37 per share). s Includes net gain on sale of surfactant and alkylphenol businesses of $26 million ($0.39 per share), on sale of forest property of $20 million ($0.20 per share), and net loss for write-off of intangible assets in its electronic materials business of $18 million ($0.27 per share). t Includes net gain on sale of interest in U.K. subsidiary of $15 million ($0.23 per share) and net loss on write-off of assets of $13 million ($0.20 per share). u Includes net gain on sale of assets of $5.0 million ($0.07 per share). v Fiscal year ends Sept. 30. w Excludes net loss on early extinguishment of debt of $9.0 million ($0.15 per share) and net gain on cumulative effect of change in accounting for income taxes of $8.3 million ($0.14 per share). x Excludes net loss on early extinguishment of debt of $4.0 million ($0.07 per share). y Includes net loss of $104 million from sale of assets in carbon products business.

Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Stockholders' equity	NET INCOME			Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
								% of sales	% of stockholders' equity	$ per share				
(Money figures in thousands of dollars unless otherwise indicated)														
Vista Chemical Corp.														
1990[a]	$718,831	$58,607[b]	$658,023	1.0	$434,892	$137,434	$(121,720)[c]	8.1%	—	$5.97[b]	$1.80	5.5 %	$43⅞–21¾	5.5
1989[a]	778,902	119,902[d]	550,594	1.4	341,109	99,011	(172,619)[c]	15.4	—	8.56[d]	1.80	3.4	62–42½	6.1
1988[a]	781,351	123,917[e]	500,643	1.6	275,544	48,082	119,438	15.9	103.8%	7.10[e]	0.35	0.9	60⅛–21⅜	5.7
1987[a]	608,887	(1,762)[f,g]	474,265	1.5	266,250	20,889	134,686	—	—	(0.13)[f,g]	0.05	0.1	54¼–17	—
Witco Corp.														
1990	$1,631,481	$67,954	$1,135,685	2.8	$471,026	$90,845	$544,272	4.2%	12.5%	$2.95	$1.72	5.6 %	$39⅞–21¾	10.4
1989	1,587,788	35,009	1,121,358	3.5	417,175	70,387	553,684	2.2	6.3	1.60	1.61	4.0	45⅛–34⅝	24.9
1988	1,585,856	71,621[h]	1,096,219	3.1	400,996	72,059	559,985	4.5	12.8	3.05[h]	1.39	4.0	38⅜–30⅝	11.3
1987	1,427,650	63,293	1,037,624	3.0	374,628	69,082	494,941	4.4	12.8	2.72	1.16	3.1	47⅜–26⅝	13.6
PHARMACEUTICALS														
Abbott Laboratories														
1990	$6,158,682	$965,774	$5,563,151	1.2	$2,375,782	$641,391	$2,833,617	15.7%	34.1%	$2.22	$0.84	2.2 %	$46⅜–31¼	17.5
1989	5,379,751	859,832	4,851,635	1.5	2,090,166	573,138	2,726,413	16.0	31.5	1.93	0.70	2.4	35⅛–23⅛	15.1
1988	4,936,991	752,027	4,825,113	1.6	1,952,622	521,196	2,464,649	15.2	30.5	1.67	0.60	2.5	26⅛–21⅜	14.3
1987	4,387,876	632,559	4,385,737	1.3	1,741,557	432,736	2,093,453	14.4	30.2	1.39	0.50	1.9	33½–20	19.3
American Home Products Corp.														
1990	$6,775,182	$1,230,597	$5,353,893	3.5	$1,437,390	$247,693	$2,392,008	18.2%	51.4%	$3.92	$2.15	4.3 %	$55–44	12.6
1989	6,747,016	1,102,158	5,114,491	3.0	1,481,686	250,737	1,403,027	16.3	78.6	3.54	1.95	4.1	54½–40⅛	13.4
1988	5,500,533	932,184	3,967,479	2.8	1,309,314	344,464	2,332,475	16.9	40.0	3.19	1.80	4.6	42⅛–35½	12.2
1987	5,028,272	845,081	3,956,855	2.0	1,153,028	216,525	1,878,178	16.8	45.0	2.86	1.67	4.2	48⅜–31	13.9
Bristol-Myers Squibb Co.														
1990	$10,300,000	$1,748,000	$9,023,000	2.0	$2,631,000	$526,000	$5,226,000	17.0%	33.4%	$3.33	$2.12	3.6 %	$68–50½	17.8
1989	9,189,000	747,000[i]	8,273,000	2.1	2,350,000	562,000	4,860,000	8.1	15.4	1.43[i]	2.00	3.9	58–44	35.7
1988	8,558,000	1,254,000	8,045,000	2.1	2,188,000	471,000	4,720,000	14.7	26.6	2.39	1.68[j]	4.0[j]	46½–36⅛[j]	14.7[j]
1987	7,558,000	1,068,000[k]	7,305,000	2.4	1,927,000	190,000[j]	4,546,000	14.1	23.5	1.98[k]	1.40[j]	3.3[j]	55¾–28¼[j]	17.0[j]
Eli Lilly & Co.														
1990	$5,191,600	$1,127,300	$6,673,700	0.9	$2,936,700	$1,007,300	$2,998,400	21.7%	37.6%	$3.90	$1.64	2.2 %	$89¾–59⅝	19.1
1989	4,175,600	939,500	5,394,400	1.7	2,114,600	554,500	3,303,500	22.5	28.4	3.20	1.35	2.4	68½–42⅜	17.3
1988	3,607,400	761,000	4,852,800	1.7	1,806,600	372,100	2,815,400	21.1	27.0	2.67	1.15	2.8	45¾–35½	15.3
1987	3,236,100	410,500[l]	4,859,200	1.8	1,642,500	344,100	2,646,900	12.7	15.5	1.41[l]	1.00	2.4	53⅝–28⅞	29.2
Merck & Co.														
1990	$7,671,500	$1,781,200	$7,872,700	1.3	$2,721,700	$670,800	$3,677,300	23.3%	48.4%	$4.56	$1.91	2.4 %	$91⅛–67	17.3
1989	6,550,500	1,495,400	6,593,400	1.8	2,292,500	433,000	3,357,300	22.8	44.5	3.78	1.64	2.4	80¾–56¼	18.1
1988	5,939,500	1,206,800	5,992,100	1.7	2,070,700	372,700	2,720,400	20.3	44.4	3.05	1.28	2.4	59⅝–48	17.6
1987	5,061,300	906,400	5,533,200	1.3	1,948,000	253,700	1,969,900	17.9	46.0	2.23	0.82	1.4	74¼–40⅝	25.8
Pfizer														
1990	$6,406,000	$801,200	$8,553,300	1.4	$2,109,800	$547,500	$4,593,300	12.5%	17.4%	$2.38	$1.20	3.5 %	$40⅞–27¼	14.3
1989	5,671,500	681,100	7,894,800	1.5	1,784,100	456,500	4,105,800	12.0	16.6	2.02	1.10	3.4	37⅞–27	16.1
1988	5,385,400	791,300	7,218,200	1.7	1,655,100	343,700	3,881,700	14.7	20.4	4.70	2.00	3.7	60¼–47⅜	11.4
1987	4,919,800	690,200	6,684,700	2.0	1,505,900	258,300	3,644,500	14.0	18.9	4.08	1.80	3.1	77–40	14.3
Schering-Plough Corp.														
1990	$3,322,900	$565,100	$3,936,900	1.3	$1,284,400	$242,900	$1,914,600	17.0%	29.5%	$2.50	$1.065	2.4 %	$50¾–37	17.6
1989	3,157,900	471,300	3,440,000	1.7	1,210,700	186,100	1,781,900	14.9	26.4	2.09	0.875	2.5	43–27⅝	16.9
1988	2,969,400	389,900	3,234,500	1.2	1,181,000	156,100	1,485,900	13.1	26.2	1.74	0.70	2.7	29⅝–22⅝	15.0
1987	2,699,300	320,700[m]	3,053,200	1.2	1,131,000	118,000	1,317,300	11.9	24.3	1.38[m]	0.51	2.4	27⅝–15⅝	15.6
Upjohn Co.														
1990	$3,020,868	$458,067[n]	$3,667,675	1.7	$1,421,570	$246,763	$1,779,625	15.2%	25.7%	$2.48[n]	$1.04	2.7 %	$44⅝–33	15.7
1989	2,724,809	323,633[o]	3,231,503	1.6	1,275,134	242,260	1,736,125	11.9	18.6	1.74[o]	0.94	2.7	42⅛–27⅝	21.8
1988	2,746,248	368,739[p]	3,139,328	1.6	1,239,598	240,997	1,820,952	12.9	19.4	1.97[p]	0.80	2.6	35¼–26⅞	15.8
1987	2,521,024	305,039	3,043,131	1.9	1,114,391	211,976	1,673,512	12.1	18.2	1.63	0.63	1.6	53¾–23¼	23.6
Warner-Lambert Co.														
1990	$4,686,900	$484,900	$3,099,700	1.2	$1,301,400	$239,900	$1,240,700	10.3%	39.1%	$3.61	$1.52	2.5 %	$70⅜–49⅝	16.6
1989	4,195,800	412,700	2,719,700	1.1	1,132,500	218,500	989,700	9.8	41.7	3.05	1.28	2.6	59⅜–37¼	15.8
1988	3,908,400	340,300	2,554,100	1.1	1,053,000	189,600	849,900	8.7	40.0	2.50	1.08	3.1	39¾–30	13.9
1987	3,484,700	295,800	2,396,500	1.1	959,800	176,900	795,000	8.5	37.2	2.08	0.885	2.6	43¾–24⅛	16.4

a Fiscal year ends Sept. 30. b Excludes cumulative effect of change in accounting for income taxes of $4.7 million ($0.44 per share). c Deficit. d Includes net gain associated with change in stock option plan of $568,000. e Includes net gain associated with change in stock option plan of $1.5 million but excludes net loss on extinguishment of debt of $10.8 million ($0.62 per share). f Net loss. g Includes net charge associated with change in stock option plan of $55.4 million and net gain on sale of interest in Petroquimica Argentina of $5.1 million but excludes net loss on extinguishment of debt of $1.9 million ($0.12 per share). h Excludes net gain on cumulative effect of accounting change of $20.3 million ($0.81 per share). i Includes charges and expenses for integrating operations of Bristol-Myers Co. and Squibb Corp., after taxes, of $693 million ($1.32 per share). j For Bristol-Myers Co. only. k Includes gain on sale of orthodontic and animal health businesses, before taxes, of $80.3 million. l From continuing operations: includes restructuring charges, before taxes, of $271.9 million ($1.58 per share) but excludes net income and net gain on sale of discontinued cosmetics business of $233.2 million ($0.79 per share). m Excludes nonrecurring net charge of $4.3 million ($0.02 per share). n From continuing operations: excludes loss on discontinued operations and their disposal of $2.4 million but includes partial pension settlement net gain of $37. 8 million. o From continuing operations: includes restructuring and other nonrecurring charges of $57.3 million but excludes net loss on discontinued operations and their disposal of $147.6 million ($0.79 per share). p From continuing operations: excludes loss from discontinued operations of $15.3 million ($0.08 per share).

Chemical employment changed little in 1990

After three years of steady growth, employment in the chemical industry leveled off last year. Overall employment in the chemicals and allied products industry rose much less than 1% in 1990, to reach nearly 1.09 million. Earlier figures, which had placed chemical employment at more than 1.1 million in early 1990, have been revised downward by the Department of Labor.

The leveling off of the number of people working in the industry was fairly uniform throughout various sectors of the chemical industry. Drug companies registered a 3% gain in employees in 1990, but many sectors—including plastics, paints, agricultural chemicals, and soap and toilet goods producers—had no change in 1990 in the size of their work force.

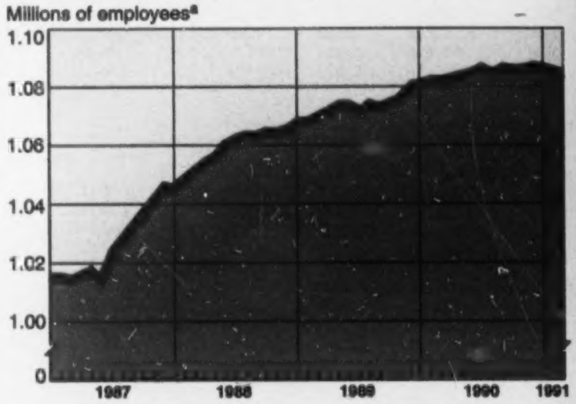
Thus, the 1990 chemical employment levels would seem to be the peak for this employment cycle, which began in late 1986. The previous peak in chemical employment occurred at the end of 1979 and in early 1980, when employment reached more than 1.11 million before dropping 9% to its most recent low of 1.02 million in 1986 and early 1987.

C&EN's company-by-company compilation of employment in the chemical industry showed a 2% overall decline in 1990 in employment at the 21 companies included in the survey. These companies together account for about one third of chemical industry employment.

The number of scientists and engineers employed in the chemical industry continued to grow modestly into 1990, posting a 1% gain over 1989 levels. These numbers reflect how many scientists and engineers are working in industry R&D in January of each year, and so trail the Labor Department's data, which are employment averages for the entire year.

Chemical industry employment is holding up a bit better than that of all manufacturing industries, which posted a 2% decline in 1990. Another indication that the chemical industry is slightly better off than manufacturing as a whole is seen in the length of the workweek. For chemical workers, it rose slightly to 42.6 hours last year, while that of all manufacturing workers eased off.

Chemical industry work force leveled off in 1990 following three years of growth



a Seasonally adjusted employment in U.S. chemicals and allied products industry; February and March 1991 figures are preliminary. Source: Department of Labor

INDUSTRIAL EMPLOYMENT: Little change in 1990 for many chemical industry sectors

Thousands[a]	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	Annual change 1989–90	Annual change 1980–90
All manufacturing	19,062	19,426	19,350	19,024	18,965	19,260	19,378	18,434	18,781	20,170	20,285	–2%	–1%
Chemicals and allied products	1,086	1,074	1,059	1,026	1,022	1,044	1,049	1,043	1,075	1,109	1,107	0	0
Industrial inorganic chemicals	135	133	133	131	135	143	143	151	161	162	161	2	–2
Plastics materials and synthetics	185	184	177	168	168	172	178	177	185	196	205	0	–1
Drugs	239	233	228	215	208	206	206	201	199	199	196	3	2
Soap, cleaners, and toilet goods	159	160	160	153	147	148	146	142	144	146	141	0	1
Paints and allied products	63	63	63	63	63	64	62	60	60	63	65	0	0
Industrial organic chemicals	153	150	146	148	154	160	162	163	171	178	174	2	–1
Agricultural chemicals	53	53	52	51	54	59	61	61	65	70	72	0	–2
Miscellaneous chemical products	100	100	101	97	94	94	92	89	91	94	93	0	1
Petroleum and coal products	160	157	160	164	169	179	189	196	201	214	198	2	–2
Rubber and miscellaneous plastics products	867	884	868	843	823	819	814	743	729	772	764	–2	1

a Domestic employment. Source: Department of Labor

PRODUCTION WORKERS: Chemical work force declined less than other manufacturing fields

Thousands[a]	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	Annual change 1989–90	Annual change 1980–90
All manufacturing	12,936	13,375	13,254	12,970	12,877	13,092	13,285	12,530	12,742	14,020	14,214	–3%	–1%
Chemicals and allied products	599	603	597	575	568	578	583	579	599	628	626	–1	0
Industrial inorganic chemicals	68	69	69	67	69	72	73	77	86	88	87	–1	–2
Plastics materials and synthetics	119	120	116	111	113	114	117	115	119	130	137	–1	–1
Drugs	106	102	101	99	96	95	96	98	98	99	97	4	1
Soap, cleaners, and toilet goods	98	101	103	98	93	94	93	89	90	92	96	–3	0
Paints and allied products	32	32	31	31	30	31	30	29	29	31	33	0	0
Industrial organic chemicals	85	87	86	83	81	82	82	84	86	90	88	–2	0
Agricultural chemicals	33	33	33	32	33	37	38	37	40	44	45	0	–2
Miscellaneous chemical products	59	59	58	55	53	54	54	51	51	54	53	0	1
Petroleum and coal products	105	103	104	107	106	109	111	118	120	134	125	2	–2
Rubber and miscellaneous plastics products	671	688	675	654	639	632	633	574	558	597	588	–2	1

a Domestic employment. **Source:** Department of Labor

EMPLOYMENT OF WOMEN: Drugs, soaps, and toiletries have highest fractions

	1989		1979	
	(thousands)	% of total	(thousands)	% of total
All manufacturing	6410.0	33%	6466.0	31%
Chemicals and allied products	318.1	30	270.7	24
Industrial inorganic chemicals	26.9	20	23.3	14
Plastics materials and synthetics	40.3	22	44.6	21
Drugs	103.4	44	79.1	41
Soap, cleaners, and toilet goods	71.3	45	55.9	40
Paints and allied products	12.5	20	12.7	18
Industrial organic chemicals	29.8	20	25.2	15
Agricultural chemicals	8.5	16	10.0	14
Miscellaneous chemical products	25.5	26	19.9	21
Petroleum and coal products	25.2	16	26.3	13
Rubber and miscellaneous plastics products	331.3	37	261.5	36

a Domestic employment. **Source:** Department of Labor

WORKWEEK: Moved upward for chemicals while all manufacturing declined

Hours[a]	1990	1989	1988
All manufacturing	40.8	41.0	41.1
Chemicals and allied products	42.6	42.4	42.2
Industrial inorganic chemicals	42.9	42.7	42.7
Plastics materials and synthetics	42.5	43.1	43.4
Drugs	41.8	41.7	41.1
Soap, cleaners, and toilet goods	40.8	40.1	40.2
Paints and allied products	41.9	41.8	41.9
Industrial organic chemicals	45.2	44.6	43.8
Agricultural chemicals	44.1	43.4	43.3
Miscellaneous chemical products	42.4	42.4	42.1
Petroleum and coal products	44.6	44.3	44.4
Rubber and miscellaneous plastics products	41.1	41.4	41.7

a For production workers in domestic employment. **Source:** Department of Labor

EMPLOYMENT OF SCIENTISTS, ENGINEERS: Growth continues for chemical industry as a whole

Thousands[a]	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980
Total, all industry	731.7	720.2	708.6	695.8	671.0	622.5	584.1	540.9	509.8	487.8	450.6
Chemicals and allied products	78.4	77.6	75.8	75.2	75.8	71.1	69.8	67.3	61.6	54.7	51.4
Drugs and medicines	33.0	34.0	33.0	32.6	31.8	30.8	30.8[b]	28.2	25.6	23.3	21.6
Industrial chemicals	23.0[b]	23.1[b]	22.5[b]	22.4[b]	24.9	23.5	25.6	26.6	25.9	21.6	20.9
Other chemicals	22.4	20.5	20.3	20.2	19.1	16.7	13.4	12.1	10.1	9.8	8.9
Petroleum refining and extraction	10.2	10.3	9.5	9.9	10.4	13.5	13.3	14.7	15.6	13.0	10.8

a Full-time equivalent number of R&D scientists and engineers in industry, as of January of each year. b Partly estimated. **Source:** National Science Foundation

3 Employment in the U.S. Chemical Industry

CHEMICAL EMPLOYMENT: Falloff returns employment to 1987 levels at major companies

Thousands	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980
Air Products	14.0	14.1	13.3	12.1	16.6	18.7	17.7	16.7	18.9	16.2	15.8
American Cyanamid	32.0	35.4	35.5	34.3	34.5	36.4	38.2	38.7	40.2	41.8	42.6
Betz Laboratories	3.7	3.4	3.1	2.0	2.6	2.5	2.5	2.3	2.2	2.2	2.1
Cabot Corp.	6.0	5.5	5.2	5.1	6.6	7.7	7.5	7.2	7.5	7.7	7.6
Chemed	6.1	5.7	5.6	4.8	4.8	4.3	4.3	4.1	3.5	3.6	3.6
Crompton & Knowles	1.8	1.7	1.6	1.3	1.3	2.3	2.3	2.4	2.3	2.5	2.8
Dow Chemical	62.1	62.1	55.5	53.1	51.3	53.2	49.8	54.5	56.6	63.8	56.8
Ethyl	5.7	5.5	10.4	10.0	10.5	10.5	11.0	13.0	14.0	14.5	15.0
H. B. Fuller	5.6	5.5	5.2	4.6	4.5	4.4	4.3	4.1	4.0	3.3	3.4
W. R. Grace	49.0	46.4	45.7	39.4	41.4	116.9	102.6	95.5	82.2	89.0	92.0
Hercules	19.9	23.3	22.7	23.2	25.1	25.4	26.3	24.2	24.5	25.9	26.1
Imcera Group	9.6	6.9	6.9	12.9	13.9	8.7	9.0	8.4	8.4	10.6	10.6
International Flavors	4.2	4.2	4.2	4.1	3.8	3.7	3.7	3.7	3.6	3.6	3.6
Lubrizol	5.2	5.3	4.8	4.8	4.8	5.2	4.2	4.2	4.3	4.2	4.2
Monsanto	41.1	42.2	45.6	49.7	51.7	56.1	50.8	48.8	52.2	57.4	61.8
Nalco Chemical	5.9	5.5	5.4	5.1	4.9	5.1	4.8	4.6	4.6	4.7	4.3
Olin	15.2	15.4	16.4	14.1	13.2	14.9	17.8	18.2	17.5	20.3	21.0
PPG Industries	35.1	35.5	36.3	36.8	36.5	37.5	37.7	37.0	37.0	36.6	37.3
Rohm & Haas	12.9	13.0	12.4	12.0	12.1	11.8	11.9	11.4	11.5	13.5	13.2
Stepan	1.3	1.2	1.0	1.0	0.9	0.9	0.9	0.9	0.9	0.9	0.8
Union Carbide	38.8	46.0	44.0	43.1	50.3	91.5	98.4	99.5	103.2	110.3	116.1
TOTAL EMPLOYEES	**375.2**	**383.7**	**380.8**	**373.6**	**391.3**	**517.7**	**505.7**	**499.3**	**499.1**	**532.6**	**540.6**
ANNUAL CHANGE	**−2.2%**	**0.8%**	**1.9%**	**−4.5%**	**−24.4%**	**2.4%**	**1.3%**	**0.1%**	**−6.3%**	**−1.5%**	**0.8%**
SALES PER EMPLOYEE ($ thousands, current)	**$203.3**	**$189.5**	**$179.3**	**$160.7**	**$135.8**	**$114.6**	**$115.8**	**$110.4**	**$107.9**	**$109.6**	**$102.0**
SALES PER EMPLOYEE ($ thousands, constant 1982[a])	**$163.3**	**$153.9**	**$154.0**	**$151.0**	**$132.5**	**$110.5**	**$112.6**	**$110.1**	**$107.9**	**$111.4**	**$114.5**

Note: Data are not restated for acquisitions, divestitures, or similar developments. a Based on producer price index for chemicals and allied products. **Source:** Company data

WAGES: Organic chemical workers are highest paid in chemical industry

	Hourly earnings[a]				Weekly earnings[a]			
	1990	1989	1988	1987	1990	1989	1988	1987
All manufacturing	$10.84	$10.47	$10.18	$ 9.91	$442.27	$429.27	$417.99	$408.31
Chemicals and allied products	13.54	13.09	$12.71	12.37	576.80	555.02	536.36	523.25
Industrial inorganic chemicals	14.67	14.19	13.83	13.57	629.34	605.91	590.54	574.88
Plastics materials and synthetics	14.02	13.44	13.06	12.60	595.85	579.26	562.80	543.06
Drugs	12.87	12.51	12.07	11.62	537.97	521.67	496.08	483.39
Soap, cleaners, and toilet goods	11.76	11.28	11.05	10.90	479.81	452.33	444.21	447.99
Paints and allied products	12.01	11.66	11.24	10.84	503.22	484.39	470.96	452.03
Industrial organic chemicals	15.97	15.65	15.30	14.89	721.84	697.99	670.14	656.19
Agricultural chemicals	13.56	12.79	12.35	11.92	598.88	555.09	534.76	510.18
Miscellaneous chemical products	12.30	11.92	11.54	11.36	521.52	505.41	485.83	471.44
Petroleum and coal products	16.23	15.41	14.97	14.58	723.86	682.66	664.67	641.52
Rubber and miscellaneous plastics products	9.79	9.47	9.19	8.98	402.37	392.06	383.22	373.71

a For production workers in domestic employment. **Source:** Department of Labor

Productivity drops for chemical industry

Productivity fell and unit labor costs rose for the chemical industry last year.

Revised government production data for chemicals and allied products has cast a new and poorer light on chemical productivity for the past few years. According to the revised data, productivity for chemicals and allied products was essentially flat between 1988 and 1989, instead of increasing 2.3% as previously reported.

Production of chemicals increased just 1.5% in 1990 over the prior year, but aggregate production workhours rose faster at 2.8%. This caused a decline in the productivity index of 1.3%.

At the same time, hourly production wages for chemicals and allied products rose 3.5% from 1989. This caused unit labor costs to increase 4.8%, making 1990 the third straight year that this index has been up.

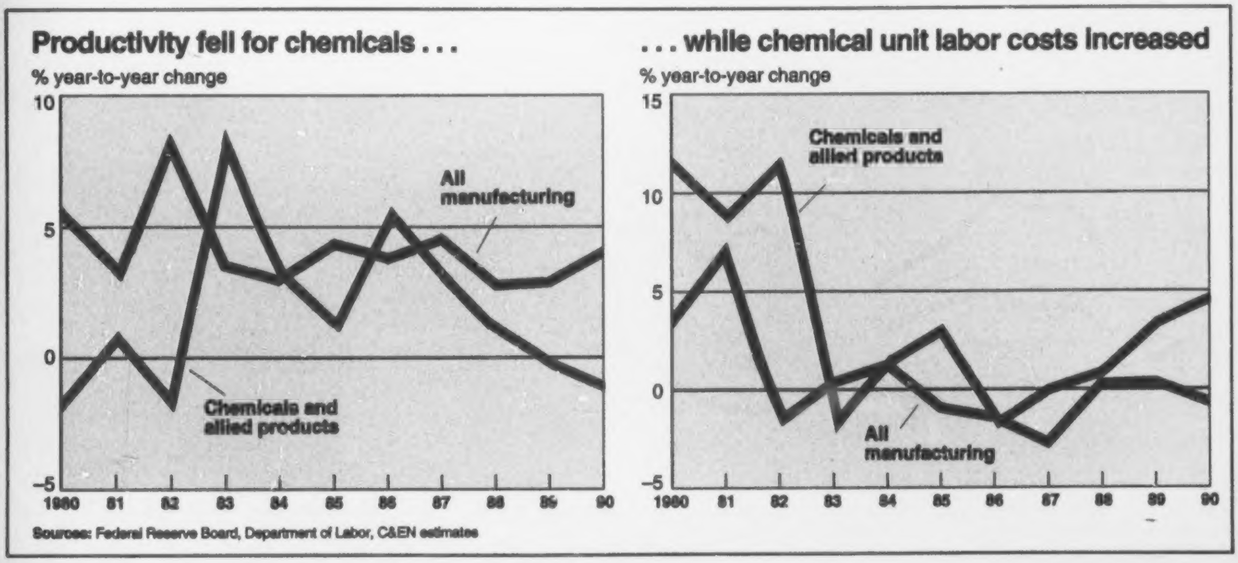
The chemical industry lagged behind all manufacturing last year in productivity. As a result of a nearly 1% increase in production, coupled with a 2.9% decline in aggregate workhours, productivity for the broad manufacturing sector increased 4.0% in 1990 over the year-earlier level.

All manufacturing industries also did much better than chemicals and allied products in terms of the cost of production. While productivity, or unit output per workhour, was rising for all manufacturing, hourly production wages were increasing at a lower 3.4%. As a result, the index for unit labor costs declined 0.9%, a much better performance than the chemical industry's 4.8% rise.

PRODUCTIVITY: Modest growth in chemical industry keeps labor costs relatively low

ndexes, 1987 = 100	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980
CHEMICALS AND ALLIED PRODUCTS											
Production	110.1	108.5	105.4	100.0	94.6	91.4	91.4	87.5	81.8	89.2	87.8
Workhours	110.0	107.0	103.8	100.0	97.8	99.4	100.3	99.2	100.5	107.4	106.7
Productivity[a]	100.1	101.4	101.5	100.0	96.7	92.0	91.1	88.2	81.4	83.1	82.3
Hourly production wages	109.5	105.8	102.3	100.0	96.7	93.6	89.8	85.7	80.6	73.7	67.2
Unit labor costs[b]	109.3	104.3	100.8	100.0	100.0	101.7	98.6	97.2	99.0	88.7	81.7
ALL MANUFACTURING											
Production	109.9	108.9	105.8	100.0	94.3	91.6	89.3	80.9	76.6	80.3	78.8
Workhours	99.9	102.9	102.9	100.0	98.5	99.7	101.5	94.4	93.1	104.8	105.6
Productivity[a]	110.0	105.8	102.8	100.0	95.7	91.9	88.0	85.7	82.8	76.6	74.6
Hourly production wages	109.7	106.1	102.9	100.0	98.3	95.9	92.8	89.3	86.0	80.9	73.6
Unit labor costs[b]	99.7	100.3	100.1	100.0	102.7	104.3	105.4	104.2	103.9	105.6	98.7

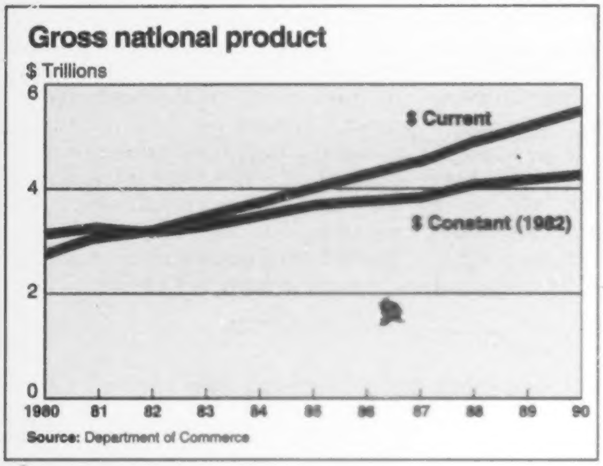
[a] Productivity is output per workhour, calculated by dividing indexes for production by indexes for workhours of production employees. [b] Unit labor costs are labor costs per unit of output, calculated by dividing indexes for wages by indexes for output per workhour. **Sources:** Federal Reserve Board, Department of Labor, C&EN estimates


Productivity fell for chemicals . . .

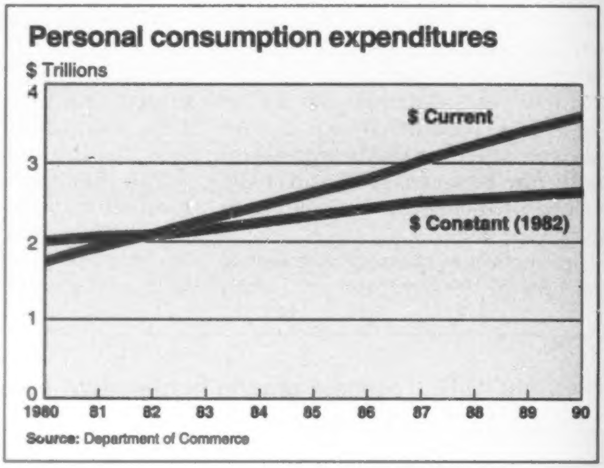
. . . while chemical unit labor costs increased

Sources: Federal Reserve Board, Department of Labor, C&EN estimates

Agriculture only growing chemical market


Gross national product

Source: Department of Commerce


Personal consumption expenditures

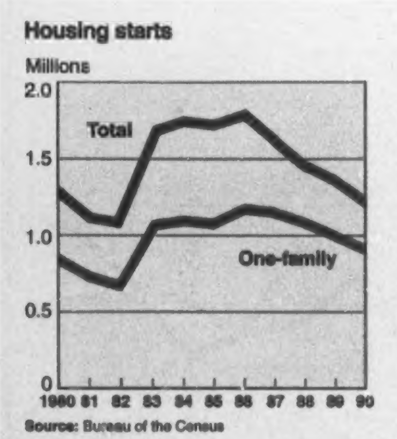
Source: Department of Commerce

No industry can long outperform its best customers. A glance at the graphs on these two pages is all that's needed to see why 1990 was a soft year for the chemical industry. The U.S. economy overall showed little growth beyond inflation last year, and most major markets for chemicals either held steady or declined.

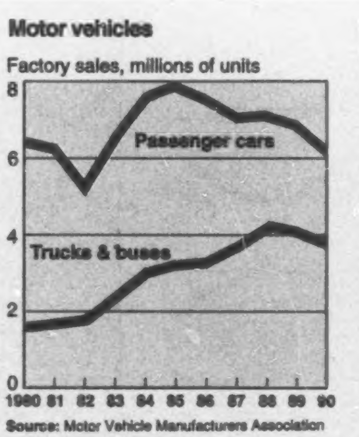
As measured by the gross national product, the U.S. economy outpaced inflation by less than 1% in 1990. Personal consumption expenditures, another broad indicator of overall economic health, also rose by less than 1% in real terms last year. And such growth as there was occurred in the early part of the year. Both GNP and personal consumption declined in the fourth quarter of 1990, a decline that continued in the first quarter of 1991. Thus, the U.S. economy officially slid into recession as 1990 came to a close. And, because the chemical industry's vast array of products are so widely used, softness in the overall economy translated into declines in the markets for chemicals.

For some of the most important chemical markets, 1990 was only the most recent in a string of poor years. New housing—a major market for plastics, synthetic fibers, and coatings—has been declining since 1986. Last year saw housing starts fall 14% to their lowest level since the recession year of 1982.

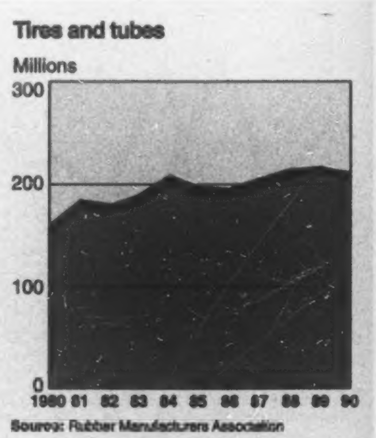
Sales of U.S.-made automobiles also have been declining steadily in recent years, and 1990 continued the


Housing starts

Source: Bureau of the Census


Motor vehicles

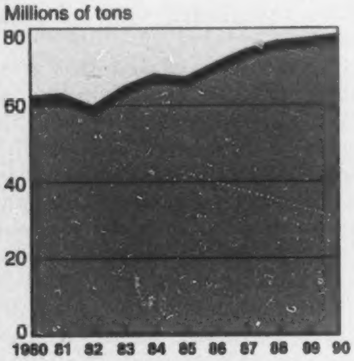
Source: Motor Vehicle Manufacturers Association


Tires and tubes

Source: Rubber Manufacturers Association trend. Sales of passenger cars dropped 11% last year, to just over 6 million units. These sales have fallen 24% from their 1985 levels. Even truck and bus sales, which held up better than cars did against foreign competition through most of the 1980s, slipped 8% in 1990.

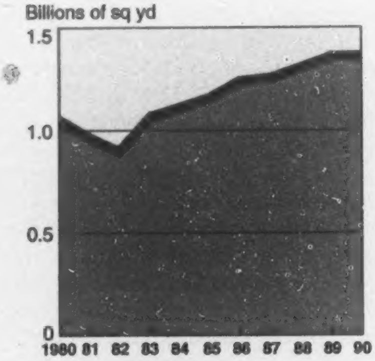
Agricultural production, on the other hand, posted a 3% increase in 1990, led by near record wheat production. Agricultural production is up for the second year in a row, and these two increases bring it back to nearly 1985 levels. Wheat acreage is expected to decline next year, while plantings of cotton, corn, and other feedgrains will be up. The overall effect may be a slight decline in fertilizer use.

Paper and paperboard



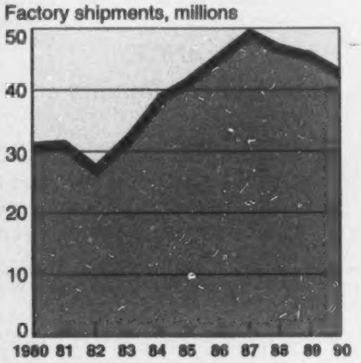
Source: American Paper Institute

Floor coverings



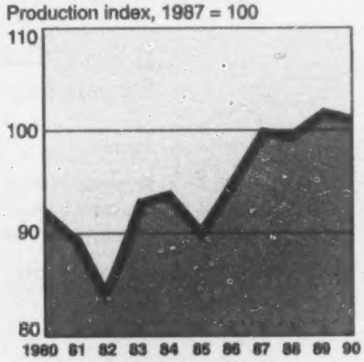
Source: Bureau of the Census

Major home electrical appliances



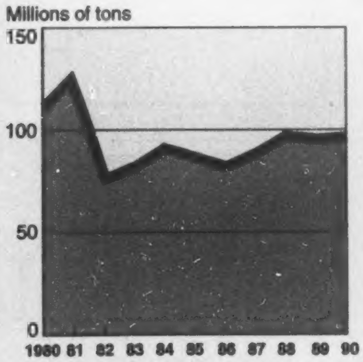
Source: Association for Home Appliance Manufacturers

Textile mill products



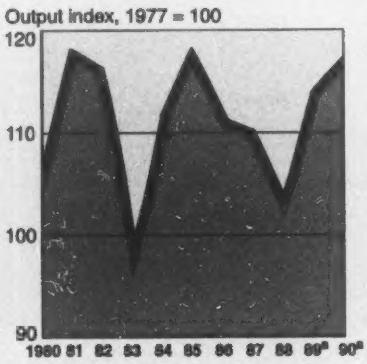
Source: Federal Reserve Board

Steel



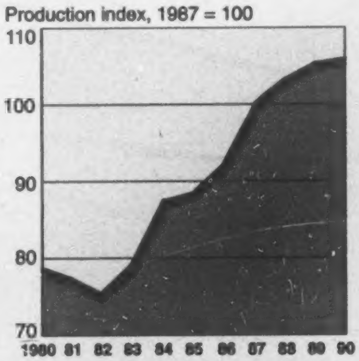
Source: American Iron & Steel Institute

Agricultural production



a Preliminary. **Source:** Department of Agriculture

Furniture and fixtures



Source: Federal Reserve Board

Chemical trade flourished as trade talks stall

Trade officials in the U.S. chemical industry concentrated their attention last year on the ill-fated Uruguay round of multilateral trade talks. These trade negotiations, held under the auspices of the General Agreement on Tariffs & Trade (GATT), fell apart in Brussels last December and now are struggling to regain their momentum.

Trade experts also spent a lot of time analyzing the consequences for the chemical industry of a possible free trade agreement that would include Mexico and Canada in a North American free trade area.

But despite the emphasis on trade politics and policy, chemical trade went on with a flourish last year. World chemical trade, measured as exports, increased 12% to $295 billion. That's a much larger gain than the 4% advance chalked up in 1989.

It's unlikely, however, that chemical trade grew that much on a volume basis. Although the U.S. dollar has been becoming stronger this year, it weakened against most major foreign currencies in 1990. It declined 6.8% against the Japanese yen, 8.9% against the German deutsche mark, and a hefty 17% against the British pound. As a result, world chemical trade measured in dollars gives an inflated view of actual growth.

The U.S. chemical industry, meanwhile, chalked up another record trade surplus of $16.5 billion. This new record came on the strength of almost $39 billion in chemical exports, up 6.9% over 1989. Chemical import growth, however, was even stronger. Imports advanced 8.3% to $22.5 billion.

Even the overall U.S. trade deficit dropped—for the third successive year—to $101 billion. The reason: Total U.S. exports advanced 8.2%, while total U.S. imports increased only 4.7%.

U.S. TOTAL TRADE BALANCE:
Deficit continues to shrink

$ Billions	1990	1989	1988	1980
Total exports	$ 394.0	$ 364.3	$ 322.4	$ 200.6
Total imports	495.0	472.9	440.9	240.8
Trade balance	−101.0	−108.6	−118.5	−40.2

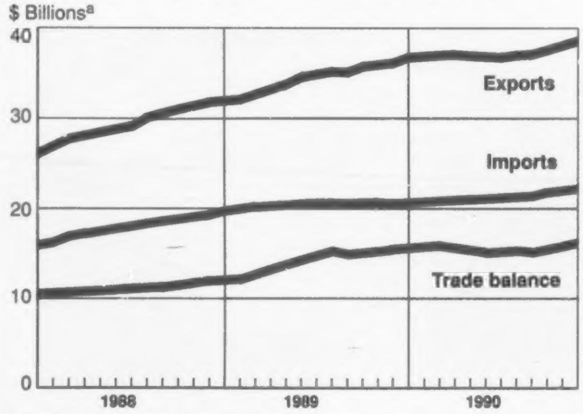
Source: Department of Commerce

U.S. CHEMICAL TRADE BALANCE:
Surplus increases despite strong imports

$ Millions	1990	1989	1988	1980
Chemical exports	$38,983	$36,485	$31,909	$20,740
Chemical imports	22,468	20,752	20,326	8,594
Chemical trade balance	16,515	15,733	11,583	12,146

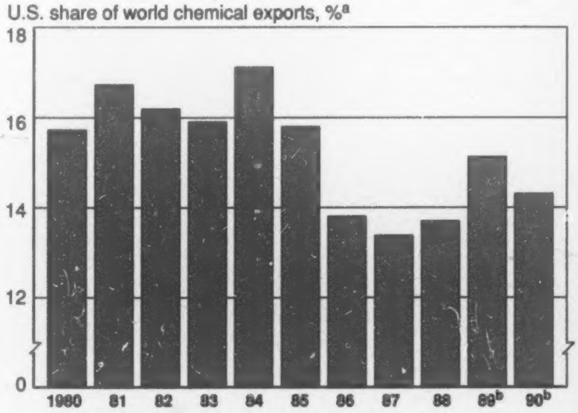
Note: Data for 1990, 1989, and 1988 have been revised according to SITC (Standard International Tariff Classification) revision 3. Earlier data have not been revised. **Source:** Department of Commerce

U.S. chemical trade balance inches up . . .



a Running 12-month totals. **Source:** Department of Commerce

. . . although export market share drops



a U.S. chemical exports as a percentage of total world chemical exports less U.S. chemical imports. b C&EN estimates.

U.S. TRADE: Most goes to European Community

$ Millions[a]	1990	1989	1988	1980
U.S. CHEMICAL EXPORTS				
Canada	$ 6,050	$ 4,210	$ 3,751	$ 2,134
Latin America	5,773	5,419	5,083	4,846
European Community	10,509	9,758	8,318	5,149
Eastern Europe	460	409	336	88
Communist Asia	1,054	1,136	1,309	386
Japan	4,582	4,664	3,982	1,964
Middle East	629	543	542	459
Rest of Asia	6,566	6,624	5,712	2,782
Australia	1,247	1,364	1,066	645
Africa	628	702	594	721
Other	1,485	1,656	1,216	1,566
TOTAL	**$38,983**	**$36,485**	**$31,909**	**$20,740**
U.S. CHEMICAL IMPORTS				
Canada	$ 4,305	$ 3,934	$ 3,841	$ 2,494
Latin America	1,287	1,671	1,354	536
European Community	9,728	9,158	9,066	3,372
Eastern Europe	242	208	219	195
Communist Asia	337	273	230	107
Japan	2,391	2,373	2,399	697
Middle East	355	371	305	58
Rest of Asia	1,267	985	844	163
Australia	344	291	329	206
Africa	90	61	106	62
Other	2,122	1,427	1,633	704
TOTAL	**$22,468**	**$20,752**	**$20,326**	**$ 8,594**

a U.S. chemical trade data have been revised according to SITC (Standard International Tariff Classification) revision 3 back to 1983. Earlier data have not been revised. **Source:** Department of Commerce

WORLD TRADE: Up 12% last year

$ Millions	1990	1989	1988	1980
CHEMICAL EXPORTS				
World	$295,100[a]	$262,900[a]	$252,713	$140,748
U.S.	38,983	36,485	31,909	20,740
Canada	6,668	6,099	6,230	3,519
EC, 12 countries	162,063	141,989	139,894	78,535
Belgium-Luxembourg	16,515	13,889	13,043	7,422
France	28,173	23,941	23,634	13,249
Germany[b]	49,553	44,187	43,848	24,318
Italy	11,152	10,003	10,170	5,505
Netherlands	20,164	19,494	19,617	11,268
U.K.	23,415	20,189	20,187	12,303
Switzerland	13,749	11,008	11,137	5,680
Japan	15,872	14,776	13,964	6,767
CHEMICAL IMPORTS				
U.S.	$ 22,468	$ 20,752	$ 20,326	$ 8,594
Canada	8,011	7,764	6,577	3.249
EC, 12 countries	142,353	119,037	112,497	60,604
Belgium-Luxembourg	15,125	11,514	10,672	5,972
France	24,894	20,721	19,619	12,169
Germany[b]	29,944	25,387	24,274	13,314
Italy	20,260	17,182	16,081	7,993
Netherlands	14,224	11,539	10,828	6,393
U.K.	19,274	17,091	16,583	7,310
Switzerland	7,928	6,679	6,731	3,648
Japan	16,045	15,948	14,830	6,202

a C&EN estimates. b Data prior to 1990 are for West Germany only. **Sources:** United Nations, Organization for Economic Cooperation & Development, European Community, individual government agencies

U.S. TRADE, BY PRODUCTS: Organics account for more than a fourth of chemical exports

	Chemical exports				Chemical imports			
$ Millions[a]	1990	1989	1988	1980	1990	1989	1988	1980
Organic chemicals	$10,400	$10,609	$ 9,704	$5,697	$ 7,392	$ 7,042	$ 7,250	$2541
Plastics in primary form	6,428	5,727	5,503	3,884	1,974	1,687	1,373	647
Medicinals and pharmaceuticals	4,103	3,660	3,262	1,932	2,500	2,086	1,849	509
Inorganics	3,816	4,319	4,289	2,939	3,234	3,231	3,147	2314
Plastics in nonprimary form	2,633	2,202	2,001	b	1,774	1,629	1,574	b
Fertilizers, manufactured	2,574	2,821	1,199	2,265	955	999	991	1105
Essential oils and perfume materials	1,963	1,469	1,126	806[c]	1,323	1,165	1,175	374[c]
Dyeing, tanning, and coloring materials	1,588	1,097	1,100	490	1,288	1,133	1,302	284
Other	5,478	4,583	3,725	2,707	2,028	1,780	1,665	820
TOTAL	**$38,983**	**$36,485**	**$31,909**	**$20,740**	**$22,468**	**$20,752**	**$20,326**	**$8594**

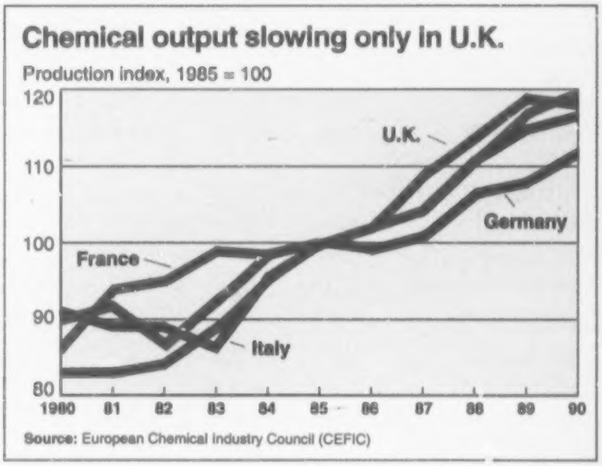
a U.S. chemical trade data have been revised according to SITC (Standard International Tariff Classification) revision 3 back to 1983. Earlier data have not been revised. b No such classification in 1980. c Included cleansing and polishing materials in 1980. **Source:** Department of Commerce

Slowdown hits West European chemicals

Business slowed down for the West European chemical industry in 1990. Only in Germany, where markets were buoyed up by demand from recently re-unified eastern states, did companies continue the growth of previous years.

Although the dollar figures show healthy growth, much of that is due to exchange rate fluctuations; in local currencies, growth has been much more modest. Chemical output rose 2% in volume in 1990, considerably less than in 1989. Pharmaceuticals and detergents showed some production strength, but output was weak for fertilizers, organics, and fibers.

Results in 1990 showed the painful turn from a solidly profitable year in 1989 to one marked by rising oil and raw materials prices only incompletely offset by producers' price increases. The inexorable result: lower profit margins throughout the industry. However, chemical companies maintained capital spending programs.



Chemical output slowing only in U.K.

Source: European Chemical Industry Council (CEFIC)

CHEMICAL INDUSTRY TRENDS: Sales in U.S. dollars rebound after a lackluster 1989

$ Billions (U.S.)	1990	1989	1988	1987	1986
GERMANY					
Sales	$100.6	$ 85.2	$ 85.7	$ 78.0	$ 64.5
Exports	52.3	45.7	45.5	40.2	33.2
Imports	32.8	27.3	25.6	22.6	18.8
Capital spending	7.7	6.1	[illegible].0	5.3	3.5
Production index[a]	112.4	109.4	10[illegible].5	101.1	99.1
Price index[a]	93.8	95.2	92.4	9[illegible].1	94.2
Employees (thousands)	592	582	575	572	567
FRANCE[b]					
Sales	$ 64.2	$ 54.2	$ 53.5	$ 47.4	$ 40.7
Exports	26.7	22.8	21.9	19.0	15.7
Imports	23.5	19.4	18.2	15.4	12.5
Capital spending	4.2	3.1	2.9	2.5	1.9
Production index[a]	120.3	118.2	111.4	104.1	101.0
Price index[a]	103.2	103.2	98.8	96.3	97.5
Employees (thousands)	263	264	257	268	268
U.K.[b]					
Sales	$ 50.6	$ 44.7	$ 44.0	$ 36.9	$ 30.6
Exports	23.7	20.5	20.2	17.3	14.3
Imports	19.3	17.1	16.6	13.7	11.0
Capital spending	3.3	3.1	3.1	2.3	1.9
Production index[a]	118.2	119.3	113.9	109.0	101.1
Price index[a]	121.7	116.4	111.5	105.8	101.4
Employees (thousands)	317	323	320	336	336

$ Billions (U.S.)	1990	1989	1988	1987	1986
ITALY					
Sales	$ 51.6	$ 44.2	$ 43.8	$ 37.5	$ 30.7
Exports	12.9	11.5	10.9	9.3	7.8
Imports	21.6	18.4	17.1	14.7	12.0
Capital spending	2.9	2.4	2.1	1.8	1.3
Production index[a]	117.1	115.0	112.5	103.6	101.4
Price index[a]	111.5	110.7	107.5	100.4	97.3
Employees (thousands)	217	220	223	225	230
SPAIN[c]					
Sales	$ 40.3	$ 32.5	$ 30.4	$ 25.8	$ 20.7
Exports	6.2	5.2	4.9	4.2	3.1
Imports	10.4	8.6	7.6	6.3	4.7
Capital spending	1.0	0.9	0.7	0.5	0.4
Production index[a]	132.5	128.6	122.5	112.4	105.0
Price index[a]	112.1	108.3	104.6	102.5	101.0
Employees (thousands)	240	240	239	239	239
BELGIUM[b,c,d]					
Sales	$ 28.1	$ 23.4	$ 22.7	$ 19.8	$ 17.2
Exports	20.7	17.3	16.4	14.7	12.2
Imports	17.4	14.3	13.5	10.7	8.6
Capital spending	2.7	1.8	1.6	1.0	0.7
Production index[a]	132.3	124.9	120.2	110.6	102.6
Price index[a]	98.8	102.1	96.5	94.0	97.7
Employees (thousands)	97	95	92	91	91

$ Billions (U.S.)	1990	1989	1988	1987	1986
NETHERLANDS					
Sales	$ 26.3	$ 22.4	$ 22.4	$ 19.5	$ 16.0
Exports	24.1	22.1	21.8	19.0	15.7
Imports	14.2	15.2	12.6	11.5	9.5
Capital spending	2.4	2.0	1.5	1.5	1.2
Production index[a]	120.0	118.0	112.0	104.0	100.0
Price index[a]	89.0	92.0	86.0	87.0	85.4
Employees (thousands)	93	93	92	91	91
SWITZERLAND[b]					
Sales	$ 15.4	$ 12.6	$ 12.7	$ 11.5	$ 9.3
Exports	13.3	10.9	10.8	9.8	7.9
Imports	7.6	6.6	6.4	5.6	4.7
Production index[a]	119.6	119.0	109.4	105.3	102.1
Price index[a]	97.9	93.0	91.9	90.8	97.3
Employees (thousands)	73	72	70	69	68
SWEDEN					
Sales	$ 8.4	$ 7.3	$ 7.5	$ 6.3	$ 5.0
Exports	4.3	3.7	3.6	3.0	2.5
Imports	5.2	4.7	4.6	3.9	3.2
Capital spending	0.7	0.5	0.5	0.5	0.4
Production index[a]	119.5	115.0	119.6	106.3	99.3
Price index[a]	118.0	116.0	110.5	103.2	101.6
Employees (thousands)	41	42	43	45	42
AUSTRIA[c]					
Sales	$ 8.0	$ 7.0	$ 7.0	$ 6.1	$ 3.5
Exports	3.5	3.0	3.0	2.4	1.9
Imports	4.9	3.9	3.8	3.4	2.7
Capital spending	0.9	0.6	0.6	0.5	0.5
Production index[a]	105.4	103.8	100.0	87.3	100.8
Employees (thousands)	57	57	56	55	35
PORTUGAL					
Sales	na	$ 4.6	$ 4.8	$ 1.7	$ 1.5
Exports	$ 1.0	0.9	0.8	0.6	0.5
Imports	2.8	2.1	1.9	1.8	0.9
Production index[a]	na	172.2	163.2	151.9	112.0
Employees (thousands)	na	64	51	51	51

$ Billions (U.S.)	1990	1989	1988	1987	1986
IRELAND[b]					
Sales	$ 4.7	$ 3.7	$ 3.1	$ 2.5	$ 2.2
Exports	3.8	3.0	2.5	1.9	1.7
Imports	2.6	2.2	2.0	1.7	1.4
Production index[a]	149.0	144.8	124.1	108.1	99.2
Price index[a]	92.5	96.8	93.4	91.7	96.8
Employees (thousands)	14	13	12	12	12
DENMARK					
Sales	$ 4.1	$ 3.4	$ 3.6	$ 3.7	$ 2.8
Exports	3.3	2.8	2.7	2.4	1.9
Imports	3.7	3.1	3.1	2.8	2.4
Capital spending	0.3	0.3	0.3	0.3	0.2
Production index[a]	111.0	111.0	107.0	105.4	108.0
Price index	112.0	109.0	104.0	99.0	97.4
Employees (thousands)	27	27	26	26	26
FINLAND					
Sales	na	$ 4.0	$ 3.5	$ 3.6	$ 3.1
Exports	$ 1.7	1.5	0.6	0.6	1.2
Imports	2.9	2.6	1.0	1.1	2.1
Capital spending	na	0.4	0.4	0.5	0.4
Production index[a]	116.8	120.2	113.4	92.1	102.1
Price index[a]	109.1	107.8	102.4	95.0	95.5
Employees (thousands)	na	20	20	24	24
NORWAY					
Sales	$ 3.6	$ 3.1	$ 3.1	$ 2.9	$ 2.3
Exports	2.2	1.9	1.9	1.6	1.3
Imports	2.2	1.9	1.9	1.6	1.4
Capital spending	na	0.2	0.2	0.2	0.2
Production index[a]	114.0	108.6	103.0	103.0	100.0
Price index[a]	120.3	122.0	114.0	106.0	101.5
Employees (thousands)	15	14	14	15	15

a 1985 = 100. b Excludes fibers. c Includes rubber and plastics processing. d Includes Luxembourg for exports and imports. na = not available. **Sources:** National agencies, European Chemical Industry Council (CEFIC)

NOTE ON CURRENCY CONVERSION

For monetary statistics in this section, European currencies were converted to U.S. dollars by the following conversion rates:

	$1.00 (U.S.) is equivalent to:				
	1990	1989	1988	1987	1986
Austria (schillings)	11.37	13.23	12.35	12.65	15.27
Belgium (francs)	33.42	39.40	36.77	37.33	44.67
Denmark (crowns)	6.19	7.31	6.73	6.84	8.09
Finland (marks)	3.82	4.29	4.18	4.40	5.07
France (francs)	5.45	6.38	5.96	6.01	6.93
Germany (marks)	1.62	1.88	1.76	1.80	2.17
Ireland (pounds)	0.603	0.705	0.654	0.672	0.745
Italy (lire)	1198	1372	1302	1297	1491
Netherlands (guilders)	1.82	2.12	1.98	2.03	2.45
Norway (crowns)	6.26	6.90	6.52	6.74	7.39
Portugal (escudos)	142.6	157.5	144.0	141.0	150.0
Spain (pesetas)	101.93	118.38	116.49	123.48	140.05
Sweden (crowns)	5.92	6.45	6.13	6.34	7.14
Switzerland (francs)	1.39	1.64	1.46	1.49	1.80
U.K. (pounds)	0.560	0.610	0.562	0.610	0.682

Source: International Monetary Fund

MAN-MADE FIBERS: Overall production of cellulosics holds steady, other fibers fall 7%

Millions of lb	1990		1989		1988		1987		1986		Change, 1989-90	
	Non-cellulosics	Cellulosics	Non-cellulosics	Cellulosics	Non-cellulosics	Cellulosics	Non-cellulosics	Cellulosics	Non-cellulosics	Cellulosics	Non-cellulosics	Cellulosics
Germany	1854	396	1841	394	1817	376	1806	356	1738	354	0%	0%
Italy	1010	79	1412	77	1452	70	1441	64	1430	66	−29	3
Spain	585	79	592	88	590	81	591	78	601	80	−2	−10
Benelux countries	568	117	521	119	385	119	399	109	379	108	9	−2
Turkey	534	20	645	20	592	20	572	18	504	18	−17	0
U.K.	506[a]	266[b]	493[a]	255[b]	515[a]	238[b]	513[a]	208[b]	524[a]	207[b]	3	4
France	343	0	392	4	392	33	382	50	392	45	−13	—
Switzerland	260	0	264	0	255	0	227	0	216	0	−2	—
Ireland	205	0	207	0	176	0	172	0	162	0	−1	—
Portugal	141	1	141	2	128	2	139	2	136	2	0	−50
Austria	84	297	77	301	70	290	68	264	61	271	9	−1
Finland	11	141	7	143	7	132	4	118	3	121	57	−1

a Includes cellulose acetate filament. b Excludes cellulose acetate filament. **Source:** Comité International de la Rayonne et des Fibres Synthétiques

PRODUCTION: German production holds up best amid overall declines

Millions of lb	1990	1989	1988	1987	Change 1989-90
FRANCE					
Sulfuric acid	8306	9141	8846	8618	−9%
Hydrochloric acid	1488	1525	1507	1427	−2
Chlorine	2956	3185	3121	2971	−7
Sodium hydroxide	3143	3370	3258	3123	−7
Carbon black	556	595	531	511	−7
Ammonia	3257	3249	4031	4466	0
Benzene	1434	1474	1544	1439	−3
Toluene	74	74	104	72	0
Xylenes	na	372	493	284	—
Ethylene	4948	5562	5361	5319	−11
Propylene	3157	3480	3298	3073	−9
Butadiene	619	724	737	677	−15
Formaldehyde	220	221	193	180	0
Polyethylene	2461	2549	2620	2523	−4
Polypropylene	1715	1544	1278	1159	11
Polystyrene	1193	1192	1177	1166	0
Polyvinyl chloride	2265	2350	2237	2039	−4
Synthetic rubber	1151	1300	1251	1184	−12
Nitrogen fertilizers	4655	4373	4343	na	6
Phosphate fertilizers[a]	626	594	707	1209	−12
GERMANY[b,c]					
Sulfuric acid	7390	7165	7186	7260	3
Hydrochloric acid	2005	2107	2160	2179	−5
Nitric acid	4144	4807	5098	5818	−14
Chlorine	7257	7574	7701	7595	−4
Sodium hydroxide	7204	7370	7602	7523	−2
Sodium carbonate	3177	3175	3089	3195	0
Sodium sulfate	389	379	385	361	3
Carbon black	866	884	836	796	−2
Ammonia	3561	4573	4816	5098	−22
Benzene	3231	3443	3536	3316	−6
Toluene	1145	919	1013	884	25
Xylenes	1287	1345	1296	1102	−4
Aniline	na	376	386	309	—
Ethylene	6604	6588	6889	6118	0
Propylene	3914	3819	3396	3467	3
Butadiene	1699	1579	1677	1543	8
Ethylene oxide	1355	1482	1381	1223	−9
Ethylene glycol	457	543	521	536	−16
Propylene oxide	1319	1299	1209	1181	2
Propylene glycol	401	399	427	379	0
***n*-Butanol**	777	741	685	689	5
Acetaldehyde	786	709	789	727	11
Acetic acid	716	701	754	704	2
Ethanol	236	224	228	240	5
Methanol	1635	1535	na	na	7%
Formaldehyde	1497	1534	1505	1341	−2
Phthalic anhydride	501	506	612	522	−1
Polyethylene	3223	3064	3235	2980	5
Polyvinyl chloride	2890	2948	3105	2904	−2
Synthetic rubber	1152	1119	1101	1035	3
Nitrogen fertilizers[d]	1870	1500	na	1674	25
Phosphate fertilizers[a]	185	197	na	na	−6
ITALY[c]					
Sulfuric acid	7281	7084	9478	9590	−7
Nitric acid	2293	2443	2625	2629	−6
Hydrochloric acid	1635	1400	2218	1496	17
Phosphoric acid	544	618	785	843	−12
Chlorine	2242	2349	2385	2294	−5
Sodium hydroxide	2448	2598	2618	2676	−6
Sodium perborate	271	276	242	245	−2
Carbon black	398	446	442	420	−11
Ammonia	3266	3882	3846	3839	−16
Benzene	1390	1447	1368	1311	−4
Toluene	435	338	480	402	29
Xylenes	958	1023	986	1067	−6
Formaldehyde	243	258	277	297	−6
Acetic acid	21	99	145	140	−79
Polyethylene	2019	1937	1822	1691	4
Polystyrene	613	590	627	664	4
Polyvinyl chloride	1312	1801	1740	1380	−27
Nitrogen fertilizers[d]	5356	6210	7176	6999	−14
U.K.					
Sulfuric acid	4402	4744	4967	4797	−7
Hydrochloric acid[e]	358	367	388	384	−3
Chlorine	2073	na	na	2256	—
Benzene	1846	2292	2072	2005	−18
Ethylene	3287	4346	4464	3955	−25
Propylene	1412	1753	2985	1929	−20
Butadiene	430	497	527	509	−16
Titanium dioxide[e]	na	593	586	562	—
Acetone	283	287	280	259	−1
Formaldehyde	176	176	246	250	0
Polyethylene	967[f]	894	716	956	8
Polypropylene	798	671	659	597	19
Polyvinyl chloride	770	736	740	774	5
Synthetic rubber	659	687	688	565	−4

a As P_2O_5. b Data prior to 1990 are for West Germany only. c Data for 1990 are C&EN estimates. d As N. e Manufacturers' sales. f C&EN estimates. na = not available. **Sources:** British Plastics Federation, government agencies for each country

COMPANY RESULTS: Capital spending and R&D remain strong despite generally lower profits

$ Millions	Net sales	Net income	Profit margin[a]	Capital spending	R&D spending	Employees (thousands)
BASF (Germany)						
1990	$28,779.6	$ 683.3	2.4%	$2751.9	$1277.2	134.6
1989	25,328.2	1071.9	4.2	2104.3	1039.4	137.0
1988	24,925.0	813.8	3.2	1985.8	1016.5	134.8
1987	22,354.4	586.1	2.6	1532.2	896.1	133.8
Hoechst (Germany)						
1990	$27,692.6	$1046.9	3.8%	$2098.1	$1658.6	172.9
1989	24,413.8	1133.0	4.6	1700.5	1394.1	169.3
1988	23,275.0	1144.9	4.9	1579.5	1372.7	164.5
1987	20,531.1	848.9	4.1	1330.0	1231.7	167.8
Bayer (Germany)						
1990	$25,705.6	$1174.7	4.6%	$2275.9	$1690.1	171.0
1989	23,031.4	1125.5	4.9	1833.5	1433.5	170.2
1988	22,993.2	1090.3	4.7	1786.9	1397.7	165.7
1987	20,635.0	857.8	4.2	1425.0	1301.7	164.4
ICI (U.K.)						
1990	$23,046.4	$1101.8[b]	4.8%	$1808.9	$1212.5	132.1
1989	21,591.8	1524.6[c]	7.1	1770.5	1047.5	133.8
1988	20,816.7	1567.6[d]	7.5	1443.1	1005.3	130.4
1987	18,234.4	1245.9	6.8	1160.7	755.7	127.8
Rhône-Poulenc (France)						
1990	$14,460.6	$ 356.3	2.5%	$1376.1	$ 972.5	91.6
1989	11,452.7	641.4	5.6	1099.7	662.9	85.6
1988	10,962.1	580.0	5.3	990.1	641.4	79.7
1987	9,344.3	392.7	4.2	830.4	585.4	83.0
Ciba-Geigy (Switzerland)						
1990	$14,174.8	$ 743.2	5.2%	$[illegible]480.6	$1475.5	94.1
1989	12,565.9	949.4	7.5	1211.6	1265.2	92.6
1988	12,087.0	907.5	7.5	1106.8	1230.8	88.8
1987	10,579.9	738.3	7.0	918.1	1122.8	86.1
EniChem (Italy)						
1990	$12,570.9	$ (56.7)[e]	—	$1530.9	$ 268.8	49.0
1989	11,185.9	521.9	4.7	1445.5	na	52.7
1988[f]	11,261.1	627.5	5.6	920.1	na	54.7
1987	na	na	na	na	na	na
Norsk Hydro (Norway)						
1990	$ 9,739.9	$ 463.4	4.8%	$1255.8	$ 164.9	33.0
1989	9,612.9	389.4	4.1	1316.8	117.5	32.8
1988	9,206.7	526.7	5.7	1355.2	113.5	39.5
1987	8,086.5	311.0	3.8	1451.0	97.2	39.1
Akzo (Netherlands)						
1990	$ 9,475.8	$ 393.4[g]	4.2%	$ 604.4	$ 489.6	69.8
1989	8,837.8	450.1	5.1	613.2	426.4	70.9
1988	8,374.2	446.0	5.3	641.4	409.0	71.1
1987	7,652.7	354.6[h]	4.6	539.4	362.1	67.4
Sandoz (Switzerland)						
1990	$ 8,897.1	$ 695.7	7.8%	$ 913.7	$ 869.1	52.6
1989	7,620.1	584.1	7.7	656.1	673.2	50.7
1988	6,986.3	521.2	7.5	573.3	624.7	48.0
1987	6,026.2	420.8	7.0	421.5	540.3	44.0

$ Millions	Net sales	Net income	Profit margin[a]	Capital spending	R&D spending	Employees (thousands)
Degussa (Germany)						
1990[i]	$ 8595.7	$ 90.7	1.1%	$ 420.4	$ 282.7	35.0
1989[i]	7636.7	93.1	1.2	282.4	224.5	33.7
1988[i]	7730.1	83.0	1.1	255.3	213.1	32.4
1987[i]	6510.6	67.2	1.0	230.9	150.0	30.8
Solvay (Belgium)						
1990	$ 7637.4	$532.6[j]	7.0%	$1092.2	$ 384.4	45.7
1989	6517.8	524.6[k]	8.0	781.7	304.6	45.1
1988	6,893.3	410.9[l]	6.0	644.5	293.4	44.3
1987	5989.8	325.9[m]	5.4	498.3	247.1	45.0
Roche Group (Switzerland)						
1990	$ 6956.8	$682.0	9.8%	$ 652.5	$1038.8	52.7
1989	5984.1	519.5	8.7	553.7	865.2	50.2
1988	5571.9[n]	439.7[n]	7.4	446.6	828.9	47.2[n]
1987	5171.1	323.5	6.3	348.8	715.8	47.5
DSM (Netherlands)						
1990	$ 5584.6	$445.6[o]	8.0%	$ 719.8	$ 233.5	24.9
1989	5081.1	488.2[p]	9.6	820.8	188.7	30.0
1988	5111.6	399.5[q]	7.8	667.7	181.8	28.6
1987	4422.6	260.6[r]	5.9	431.0	140.4	27.9
Air Liquide (France)						
1990	$ 5305.3	$361.7	6.8%	$ 727.6	$ 265.1	na
1989	4428.1	283.1	6.4	471.6	139.5	27.0
1988	4299.8	265.8	6.2	384.9	121.3	na
1987	3903.5	231.4	5.9	341.8	110.1	na
BOC International (U.K.)						
1990	$ 4721.3	$432.0	9.2%	$ 550.0	$ 111.1	40.0
1989	3785.4	375.9	9.9	565.2	89.5	38.4
1988	3771.4	365.1[s]	9.7	523.5	83.3	38.8
1987	3211.6	273.4[t]	8.5	362.5	61.5	35.5
Nobel Industries (Sweden)						
1990	$ 4459.3	$175.2[u]	3.9%	$ 410.3	na	26.7
1989	3424.5	214.0	6.2	224.7	na	22.2
1988	3488.1	152.3	4.4	176.3	na	22.1
1987	2195.6	98.1[v]	4.5	162.9	na	18.1
Courtaulds (U.K.)						
1990[w]	$ 3413.6	$258.0[x]	7.6%	na	$ 71.4	na
1989[w]	3121.3	206.6[y]	6.6	na	67.0	24.0
1988[w]	2932.4	197.5[z]	6.7	na	60.3	20.8
1987[w]	2452.5	180.3[aa]	7.4	na	na	23.7
Schering Group (Germany)						
1990	$ 3656.2	$159.5	4.4%	$ 318.5	$ 577.0	26.7
1989	3109.0	119.7	3.9	244.1	373.4	25.3
1988	2995.5	89.2	3.0	233.5	358.0	24.7
1987	2611.7	79.4	3.0	220.0	311.7	24.0
Kemira (Finland)						
1990	$ 2979.6	$ 43.7[bb]	1.5%	$ 306.8	na	15.3
1989	2570.7	40.9	1.6	374.1	na	16.0
1988	2207.7	117.4	5.3	345.7	na	14.9
1987	1942.7	64.4	3.3	644.8	na	13.6

Note: All corporate consolidated sales exclude sales of companies owned less than 50%. a Net income as a percentage of sales. b Excludes nonrecurring gain of $94.6 million. c Excludes nonrecurring gain of $208.2 million. d Excludes nonrecurring loss of $78.3 million. e Net loss. f Pro forma. g Excludes nonrecurring loss of $35.4 million. h Excludes nonrecurring gain of $134.6 million. i Fiscal year ends Sept. 30. j Excludes nonrecurring loss of $56.6 million. k Excludes nonrecurring loss of $100.5 million. l Excludes nonrecurring loss of $136.5 million. m Excludes nonrecurring loss of $90.0 million. n Restated to reflect sale of operations. o Excludes nonrecurring gain of $25.8 million. p Excludes nonrecurring gain of $162.7 million. q Excludes nonrecurring loss of $87.9 million. r Excludes nonrecurring loss of $40.4 million. s Excludes nonrecurring loss of $42.2 million. t Excludes nonrecurring loss of $8.2 million. u Excludes nonrecurring net gain of $23.8 million. v Excludes nonrecurring gain of $17.8 million. w Fiscal year ends March 31. x Excludes nonrecurring loss of $123.2 million. y Excludes nonrecurring loss of $68.9 million. z Excludes nonrecurring gain of $218.9 million. aa Excludes nonrecurring loss of $19.7 million. bb Excludes nonrecurring loss of $47.4 million. na = not available.

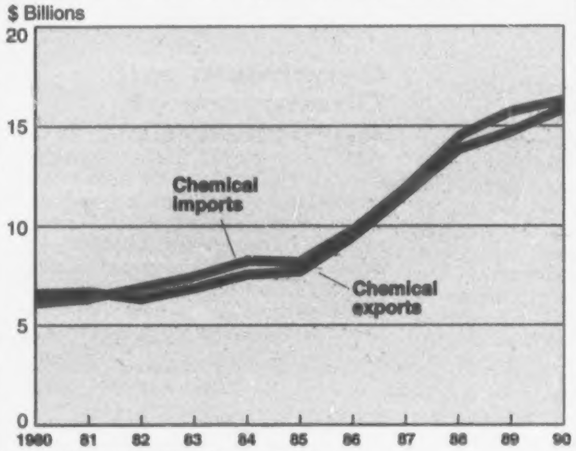
6 Foreign Chemical Industries — Japan

Japanese chemical companies ran into a difficult year in 1990. Although the Japanese economy generally was good last year, rising interest rates started to take their toll as the year wore on. Sharp oil price hikes—the result of the Middle East conflict—also dampened the economy in the second half of the year.

Despite the economic downdraft, chemical demand remained strong, particularly in the petrochemical and plastics sectors. This allowed Japanese ethylene producers to chalk up their fourth consecutive record year, with output topping 5.8 million metric tons.

However, higher feedstock prices took their toll of company profits. Profit margins dropped sharply, particularly in the second half of fiscal 1990.

Japan's chemical trade deficit shrinks



Source: Ministry of International Trade & Industry

INDUSTRY TRENDS: Plastics lead growth

Production index, 1985 = 100	1990	1989	1988	1987	Change 1989–90
All manufacturing	125.6	120.0	113.1	103.2	5%
All chemicals	134.4	128.7	120.4	111.1	4
Inorganic chemicals and pigments	114.3	114.4	108.4	100.9	0
Alkalies and chlorine	120.9	114.7	110.5	103.6	5
Organic chemicals	131.7	128.1	115.9	105.4	3
Petrochemicals	136.7	129.1	118.1	107.6	6
Aromatics	137.3	133.2	115.9	107.1	3
Cyclic intermediates and dyes	143.2	135.3	121.2	110.9	6
Plastics	139.6	130.7	120.6	109.9	7
Synthetic fibers	101.2	97.5	95.4	94.6	4
Synthetic rubber	123.1	116.7	112.2	102.9	6
Fertilizer	85.2	86.6	88.5	91.6	−2
Textile materials	126.8	118.7	117.8	110.7	7
Medicinals and drugs	154.8	147.3	136.2	123.1	5

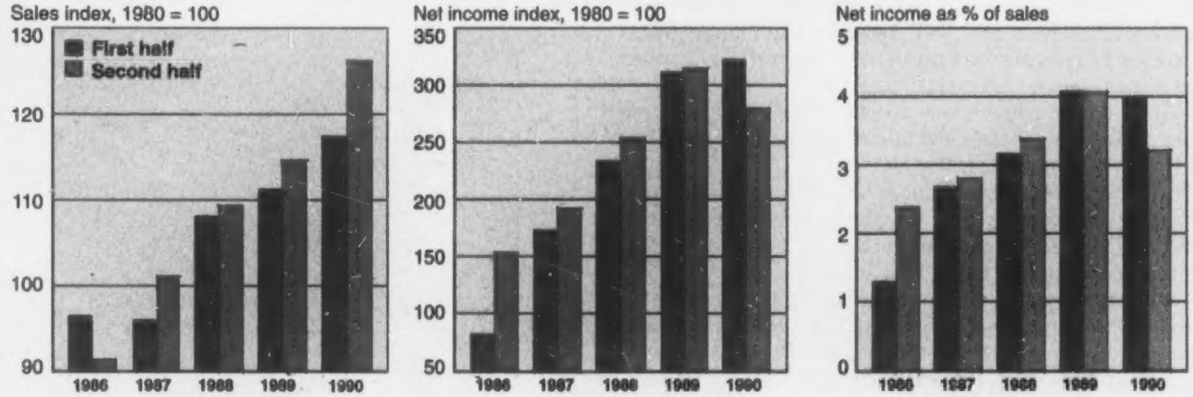
Source: Ministry of International Trade & Industry

PRODUCTION: Up for most chemicals

Thousands of metric tons, unless otherwise indicated	1990	1989	1988	1987	Change 1989–90
INORGANIC CHEMICALS					
Ammonia	1831	1831	1817	1784	0%
Ammonium chloride	246	274	299	332	−10
Ammonium sulfate	1803	1717	1834	1804	5
Calcium carbide	294	344	342	354	−15
Calcium superphosphate	472	454	476	499	4
Carbon black	783	779	720	629	1
Chlorine, liquid	1042	1009	979	911	3
Hydrochloric acid	637	571	565	543	12
Nitrogen, millions of cu m	8299	7856	6940	6452	6
Oxygen, millions of cu m	8787	8384	7707	6878	5
Sodium carbonate	1135	1105	1083	1098	3
Sodium hydroxide	3917	3674	3508	3227	7
Sodium silicate	788	756	721	664	4
Sulfuric acid	6887	6885	6766	6541	0
Titanium dioxide	280	275	258	238	2
ORGANIC CHEMICALS					
Acetaldehyde	384	356	333	285	8
Acetic acid	462	432	402	377	7
Acetone	334	337	289	260	−1
Acrylonitrile	593	611	600	573	−3
Benzene[a]	2768	2672	2374	2226	4
Butadiene	827	827	780	707	0
Butanol	300	291	276	259	3
Caprolactam	509	469	493	470	9
Cyclohexane	629	656	561	557	−4
Dioctyl phthalate	295	293	273	261	1
Ethylene	5810	5602	5057	4585	4
Ethylene dichloride	2660	2464	2301	2051	8
Ethylene glycol	501	548	349	313	−9
Ethylene oxide	674	681	510	484	−1
Methanol	84	82	141	181	2
Octanol	283	285	273	257	−1
Phenol	403	423	358	308	−5
Phthalic anhydride[a]	161	160	171	172	1
Propylene	4215	4036	3682	3370	4
Propylene glycol	298	285	265	236	5
Styrene	2215	1990	1757	1559	11
Terephthalic acid	1338	1200	1150	1048	12
Toluene	1078	1075	1019	1006	0
Toluene diisocyanate	116	104	96	91	12
Urea	776	810	790	729	−4
Xylene	2652	2488	1988	1767	7
PLASTICS					
Phenolic resins	385	375	358	332	3
Polyethylene	2888	2712	2380	2182	7
Polypropylene	1942	1719	1559	1406	13
Polystyrene	2097	1997	1891	1735	5
Polyvinyl chloride	2049	1972	1838	1663	4
SYNTHETIC RUBBER	1426	1352	1299	1192	6

[a] Petroleum-based product only. Source: Ministry of International Trade & Industry

Despite strong sales increase, profitability is declining for Japanese chemical firms



Note: Based on results of 12 leading Japanese chemical companies: Asahi Chemical, Dainippon Ink & Chemicals, Hitachi Chemical, Mitsubishi Kasei, Mitsubishi Petrochemical, Mitsui Toatsu Chemicals, Sekisui Chemical, Showa Denko, Sumitomo Chemical, Takeda Chemical Industries, Teijin, and Toray Industries. The fiscal year for most, but not all, of these companies ends March 31. **Source:** Toyo Keizai Shinposha

COMPANY RESULTS: Earnings drop for many Japanese chemical companies

$ Millions	Net sales	Net income	Profit margin[a]	Total assets	Employees (thousands)
Asahi Chemical Industry[b]					
1990	$6699	$262.4	3.9%	$6895	15.3
1989	6377	241.0	3.8	6468	15.1
1988	6384	219.4	3.4	6410	15.4
1987	5357	141.0	2.6	5241	15.6
Mitsubishi Kasei[c]					
1990	$5321	$128.1	2.4%	$6851	9.1
1989	5307	130.8	2.5	6621	8.9
1988	6132	124.9	2.0	6973	8.8
1987	4360	90.4	2.1	6002	8.9
Sumitomo Chemical[d]					
1990	$4950	$114.5	2.3%	$5587	7.8
1989	4363	145.7	3.3	5730	7.7
1988	4341	116.4	2.7	5806	7.7
1987	3609	78.6	2.2	4615	7.7
Takeda Chemical Industries[b]					
1990	$3833	$265.9	6.9%	$5020	11.0
1989	4262	271.7	6.4	5280	10.9
1988	4567	269.4	5.9	5358	10.8
1987	3777	219.6	5.8	4628	10.8
Sekisui Chemical[b]					
1990	$4144	$179.6	4.3%	$4238	5.6
1989	4018	171.6	4.3	3414	5.4
1988	3936	141.4	3.6	2919	5.2
1987	3089	64.6	2.7	2555	5.3
Toray Industries[b]					
1990	$4040	$193.4	4.8%	$5189	10.3
1989	3982	227.7	5.7	5362	9.6
1988	4317	134.7	3.1	5528	10.0
1987	3789	113.5	3.0	4854	10.6

$ Millions	Net sales	Net income	Profit margin[a]	Total assets	Employees (thousands)
Showa Denko[d]					
1990	$3934	$ 78.2	2.0%	$5439	5.3
1989	3811	97.1	2.6	4455	5.1
1988	3679	71.3	1.9	4299	5.1
1987	2908	38.8	1.3	3881	5.0
Dainippon Ink & Chemicals[b]					
1990	$3489	$ 57.3	1.6%	$4052	7.2
1989	3407	62.4	1.8	3999	6.9
1988	3440	62.2	1.8	4074	6.7
1987	2923	43.7	1.5	3366	6.6
Mitsui Toatsu Chemicals[b]					
1990	$3039	$ 69.1	2.3%	$4301	5.5
1989	2997	87.3	2.9	3963	5.4
1988	3082	83.5	2.7	3936	5.4
1987	2543	43.5	1.7	3004	5.6
Mitsubishi Petrochemical[b]					
1990	$3000	$178.5	6.0%	$4220	3.3
1989	2795	227.8	8.2	4376	3.0
1988	2654	160.0	6.0	3493	2.9
1987	2022	64.7	3.2	2843	2.8
Teijin[b]					
1990	$2279	$138.1	6.1%	$4023	5.7
1989	2217	154.9	7.0	4015	5.7
1988	2438	136.5	5.6	3823	5.8
1987	2167	109.3	5.0	3391	6.2
Hitachi Chemical[b]					
1990	$2099	$ 30.7	1.5%	$1394	5.3
1989	2052	31.7	1.5	1279	5.1
1988	2158	28.2	1.3	1261	5.0
1987	1748	20.7	1.2	1056	4.9

Note: Monetary statistics are converted from yen to U.S. dollars on the basis of $1.00 equals: 1990, 144.8 Y; 1989, 137.9 Y; 1988, 128.1 Y; 1987, 142.9 Y. Year-to-year changes in sales, net income, and assets are affected by these fluctuations in the currency exchange rate. a Net income as a percentage of sales. b Fiscal year ends March 31. c Fiscal year ends March 31 for 1990, 1989, and 1988, Jan. 31 for 1987. d Fiscal year ends Dec 31. **Sources:** Toyo Keizai Shinposha, Nihon Keizai Shimbon America

Sales and profits of Canadian chemical companies slipped last year as the country's recession ate into volume, and prices for many chemicals dropped. Inorganics were especially hard hit. Some of the trouble spots included chemicals that move into the fertilizer, pulp and paper, and construction markets.

But it could have been worse. These rough spots were more than offset by advances in petrochemical and plastics production.

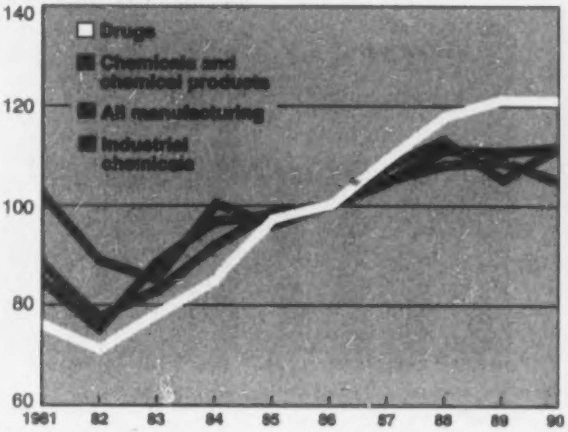
In some cases, the advances were substantial. Total polyethylene output, for instance, was up a healthy 14%, while high-density polyethylene production registered a strong 20% gain.

New capacity that came on stream last year explains some of the increase in production. But only some. Strong export markets are the other explanation.

Canadian chemical exports increased 7.7% (in Canadian dollars) last year to $6.6 billion (U.S.). Chemical shipments to the U.S., which account for almost 70% of Canadian chemical exports, were especially strong. They were up 13% (in Canadian dollars) to $4.6 billion (U.S.).

Chemical output barely inches upward

Production index, 1986 = 100



Source: Statistics Canada

Note on currency conversion: Monetary statistics in this section have been converted from Canadian dollars to U.S. dollars on the basis of $1.00 U.S. equals: 1990, $1.667 Canadian; 1989, $1.184 Canadian; 1988, $1.231 Canadian; 1987, $1.322 Canadian; 1986, $1.391 Canadian; 1985, $1.362 Canadian.

COMPANY RESULTS: Most profits dip

$ Millions (U.S.)	Sales	Net income[a]	Profit margin[b]	Capital expenditures	Employees (thousands)
Celanese Canada					
1990	$ 312.5	$ 35.4	11.3%	$ 20.7	1.8
1989	335.0	40.8	12.2	14.5	1.9
1988	330.8	39.7	12.0	19.9	2.1
1987	265.5	21.5	8.1	16.1	2.1
Du Pont Canada					
1990	$1209.4	$ 53.5	4.4%	$154.6	4.3
1989	1196.9	66.4	5.6	91.3	4.1
1988	1119.6	81.2	7.3	86.6	4.0
1987	1021.4	68.5	6.7	47.9	4.2
Nova Corp. of Alberta					
1990	$4059.2	$158.7	3.9%	$822.8	9.5
1989	4088.3	157.1	3.8	621.7	13.0
1988	3202.1	321.8	10.0	356.7	11.3
1987	1755.4	170.1	9.7	151.2	7.0
Union Carbide Canada					
1990	$ 419.1	$ −4.0	na	$ 56.5	2.5
1989	436.0	36.0	8.3%	41.7	2.6
1988	461.3	34.3	7.4	45.0	2.8
1987	318.4	19.4	6.1	26.2	2.3

a Excludes extraordinary gains and losses. b Net income as a percentage of sales. na = not available.

PRODUCTION: Inorganics weak, plastics do well

Thousands of metric tons	1990	1989	1988	1987	Change 1989–90
INORGANIC CHEMICALS					
Ammonia	3602	4054	4012	3512	−11.2%
Ammonium nitrate	1031	1056	990	844	−2.3
Ammonium phosphate	803	952	986	941	−15.6
Carbon black	178	190	181	249	−6.0
Chlorine	1542	1592	1664	1635	−3.1
Hydrochloric acid	187	180	180	164	3.8
Nitric acid	965	1027	919	900	−6.0
Phosphoric acid, 100% P_2O_5	402	470	475	464	−14.4
Sodium chlorate	658	593	503	432	11.0
Sodium hydroxide	1651	1679	1720	1770	−1.7
Sulfuric acid	3311	3560	3805	3437	−7.0
Zinc oxide	31	41	62	44	−24.4
ORGANIC CHEMICALS					
Benzene	765	670	695	720	14.3
Butadiene	192	175	182	167	9.8
Butylene	176	151	148	156	16.7
Ethylene	2425	2317	2346	2140	4.7
Formaldehyde	106	112	123	122	−4.8
Methanol	1884	2015	2101	1627	−6.5
Propylene	766	719	672	628	6.6
Toluene	427	397	417	396	7.6
Urea	2490	2402	2372	2142	3.7
Xylenes	514	432	399	345	18.8
PLASTICS					
Polyesters, unsaturated	36	37	43	47	−1.3
Polyethylene, high density	364	303	311	269	20.4
Polyethylene, low density	1167	1039	1105	1021	12.3
Polystyrene[a]	215	196	216	197	9.4

a Includes acrylonitrile-butadiene-styrene resins. **Source:** Statistics Canada

SHIPMENTS: Chemical shipments were weak last year, particularly for inorganics

$ Millions (U.S.)	1990	1989	1988	1987	1986	1985	Change 1989–90[a]
All manufacturing	$252,188	$256,099	$234,446	$203,013	$182,154	$182,526	−3%
Chemicals and chemical products	19,650	19,471	17,808	15,020	13,401	13,409	−1
Industrial chemicals, inorganic	1,998	2,064	1,949	1,780	1,570	1,605	−5
Industrial chemicals, organic	4,589	4,446	4,869	3,676	3,128	3,456	2
Plastics and synthetic resins	2,648	2,547	2,034	1,681	1,488	1,445	3
Pharmaceuticals and medicinals	3,161	3,022	2,528	2,121	1,790	1,637	3
Adhesives	178	177	168	150	136	95	−1
Paint and varnish	1,265	1,313	1,220	1,061	894	885	−5
Soaps and cleansers	1,413	1,401	1,239	1,111	1,084	1,002	−1
Toilet preparations	957	994	863	759	679	644	−5
Printing ink	216	238	208	182	192	177	−11
Synthetic fibers	907	853	791	700	610	572	5
Plastic products	4,975	5,175	4,401	3,686	3,149	2,834	−5

[a] In Canadian dollars. **Source:** Statistics Canada

CHEMICAL IMPORTS: Post a slight gain

$ Millions (U.S.)	1990	1989	1988	1987
Inorganic chemicals	$1122	$1190	$ 910	$ 396
Organic chemicals	1781	1646	1559	1270
Fertilizers and fertilizer materials	189	156	197	158
Synthetic and reclaimed rubber	241	232	228	202
Plastic materials	1299	1238	1094	831
Plastic film and sheet	435	427	392	372
Other plastic shapes and forms	421	425	430	261
Dyes, except dyeing intermediates	93	96	86	71
Pigments, lakes, and toners	115	117	115	115
Paints and related products	254	233	195	176
Other chemical products	1148	1155	951	857
TOTAL	**$7096**	**$6878**	**$6158**	**$4708**
Imports from U.S.	**$5335**	**$5060**	**$4330**	**$3609**
U.S. share	**75.2%**	**74%**	**70%**	**77%**

Source: Statistics Canada

CHEMICAL EXPORTS: Recover nicely

$ Millions (U.S.)	1990	1989	1988	1987
Chemical elements	$ 179	$ 171	$ 198	$ 167
Other inorganic chemicals	1045	1112	1145	908
Organic chemicals	1702	1542	1528	1029
Fertilizers and fertilizer materials	1422	1237	1351	960
Synthetic rubber and plastic materials	1290	1176	1276	859
Plastics, basic shapes and forms	473	404	383	380
Other chemical products	517	423	380	338
TOTAL	**$6628**	**$6063**	**$6262**	**$4639**
Exports to U.S.	**$4604**	**$4028**	**$3927**	**$2938**
U.S. share	**69.5%**	**66%**	**63%**	**63%**

Source: Statistics Canada

TRADE BALANCE: Back to a surplus . . .

$ Billions (U.S.)	1990	1989	1988	1987	1986
Total exports	$120.9	$113.0	$109.3	$91.9	$83.9
Total imports	116.5	114.1	107.0	87.9	81.3
Trade balance	4.4	−1.1	2.3	4.0	2.5

. . . as chemical trade deficit narrows

$ Millions (U.S.)	1990	1989	1988	1987	1986
Chemical exports	$ 6628	$ 6063	$ 6262	$4639	$ 3961
Chemical imports	7096	6878	6158	4708	4200
Chemical trade balance	−468	−815	−104	−69	−239

Source: Statistics Canada

PRICES: Many chemical prices drop

Price index, 1986 = 100	1990	1989	1988	Change 1989–90
All commodities	109.7	109.4	107.2	0.3%
Chemicals and chemical products	113.8	166.8	115.3	−2.6
Inorganic industrial chemicals	103.8	105.8	102.6	−1.9
Sulfuric acid	111.1	108.6	106.8	2.3
Chlorine	93.0	101.4	101.7	−8.3
Ammonia	78.4	84.3	88.7	−7.0
Organic industrial chemicals	118.3	135.0	135.2	−12.4
Benzene-toluene-xylene	126.0	125.5	98.3	0.4
Olefins	133.1	161.2	158.3	−17.4
Synthetic resins	111.3	123.0	130.8	−9.5
Polyethylene[a]	115.7	134.9	151.7	−14.2
Polystyrene	127.6	140.7	155.9	−9.3
Thermosets	119.7	125.9	121.5	−4.9
Synthetic fibers	106.6	105.5	103.4	1.0
Agricultural chemicals	106.9	102.4	101.3	4.4
Mixed fertilizers	104.7	110.8	111.0	−5.5
Pharmaceuticals	125.2	119.0	114.0	5.2
Paint and varnish	114.5	111.1	105.3	3.1
Soaps and cleansers	116.0	111.9	107.3	3.7
Toilet preparations	112.9	112.9	109.5	0.0
Pigments, lakes, and toners	106.7	105.8	106.1	0.9
Inks	103.1	101.5	100.9	1.6

[a] Includes both high- and low-density polyethylene. **Source:** Statistics Canada

In 1990, industrial production plummeted 18% in East Europe and 1.2% in the Soviet Union—the worst performance in more than four decades—as centrally planned command systems collapsed much faster than market elements could be introduced. Chemicals did worse than industry overall: Output sank 26% in Romania and Bulgaria, 25% in Poland, and 9% in Czechoslovakia. The malaise continues, with Soviet industrial output down 5% in this year's first quarter, fertilizer output down 8%, sulfuric acid 9%, and plastics 5%.

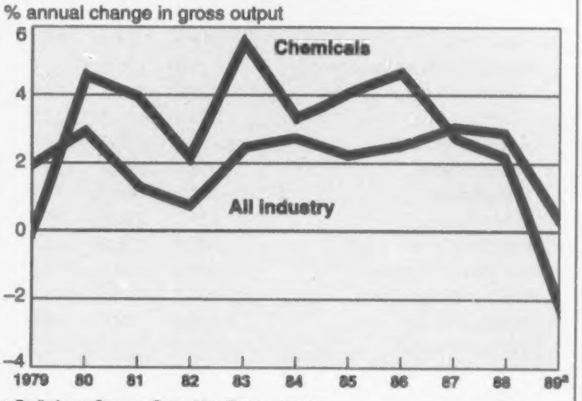
MAN-MADE FIBERS: Down substantially for both cellulosic and noncellulosic fibers

Production, thousands of metric tons	1990	1989	1988	1987	Change 1989–90
NONCELLULOSIC FIBERS					
Bulgaria	na	61	67	61	—
Czechoslovakia	143	148	147	142	−3%
Hungary	26	32	33	30	−19
Poland	113	169	168	162	−33
Romania	138	170	189	184	−19
U.S.S.R.	na	973	954	904	—
TOTAL	**na**	**1745**	**1736**	**1644**	—
CELLULOSIC FIBERS					
Bulgaria	na	5	5	33	—
Czechoslovakia	57	60	58	55	−6%
Hungary	4	4	4	4	0
Poland	36	69	77	76	−48
Romania	na	103	108	103	—
U.S.S.R.	na	584	601	613	—
TOTAL	**na**	**970**	**995**	**1029**	—

na = not available. **Source:** PlanEcon Inc.

Soviet chemical output declined in 1989 as that of all industry faltered

% annual change in gross output



a Preliminary. **Source:** Central Intelligence Agency

PRODUCTION GROWTH: Chemicals, like all industry, faced major drop in 1990

% annual change in gross output	1990	1989	1988	1987	1986
U.S.S.R. and East Europe[a]					
All industry	−6.2%	1.3%	3.8%	3.6%	4.4%
Bulgaria					
All industry	−14.1	2.2	5.1	4.2	4.0
Chemicals[b]	−25.5	3.8	5.8	5.1	4.9
Czechoslovakia					
All industry	−3.7	0.8	2.1	2.5	3.2
Chemicals[b]	−9.1	0.7	2.1	3.2	4.0
Hungary					
All industry	−4.5	−2.5	−0.3	3.5	1.9
Chemicals[b]	−5.4	−3.1	1.3	5.8	1.1
Poland					
All industry	−23.3[c]	−0.5	5.3	3.4	4.7
Chemicals	−24.7[c]	2.6	6.4	4.3	4.2
Romania					
All industry	−19.8	−2.1	3.1	2.4	7.3
Chemicals	−26.0	−3.1	3.2	−3.8	8.3
U.S.S.R.					
All industry[d]	−1.2	1.7	3.9	3.8	4.4
Chemicals[d]	−1.0	1.4	3.8	4.4	6.3
All industry[e]	na	0.2[f]	2.9	3.1	2.5
Chemicals[e]	na	−2.5[f]	2.2	2.7	4.8

a Includes East Germany. b Includes rubber industry. c Industrial sales of socialized sector. d Figures based on official Soviet statistics. e Figures based on Central Intelligence Agency estimates, giving lower results because of postulated upward bias in official figures. f Preliminary figure. na = not available. **Sources:** United Nations Economic Commission for Europe and state central statistical bureaus, Central Intelligence Agency, PlanEcon Inc.

AGRICULTURAL CHEMICALS: Fertilizer supplies continue to fall in Soviet Union

Thousands of metric tons	1990	1989	1988	1987	1986
Bulgaria					
Fertilizer supply[a]	na	na	781	745	808
Pesticide supply[b]	na	na	26.3	28.5	36.5
Czechoslovakia					
Fertilizer supply[a,c]	na	1,565	1,594	1,562	1,702
Hungary					
Fertilizer supply[a]	na	1,302	1,418	1,373	1,383
Poland					
Fertilizer supply[a,c]	na	3,625	3,277	3,583	3,413
Pesticide supply[b]	na	21.0	23.4	18.4	14.5
Romania					
Fertilizer supply[a]	na	1,194	1,426	na	1,386
U.S.S.R.					
Fertilizer supply[a]	21,500	24,482	27,196	27,412	26,514
Nitrogen[a]	8,900[d]	9,918	11,587	11,787	11,475
Phosphate[a,e]	7,000[d]	8,175	8,556	8,564	8,354
Potassium[a]	5,600[d]	6,381	7,044	7,052	6,677

a Nutrient content basis, as N, P_2O_5, or K_2O. b On basis of active substance. c For year ending June 30. d Estimated value. e Includes ground phosphate rock. na = not available. **Sources:** Department of Agriculture, Central Intelligence Agency, official national statistics from state central statistical bureaus

PRODUCTION: Further declines for most countries' chemical products in 1990

Thousands of metric tons	1990	1989	1988	1987	1986
U.S.S.R.					
Sulfuric acid	27,300[a]	28,276	29,372	28,531	27,847
Mineral fertilizers[b]	31,700[a]	34,254	37,138	36,334	34,737
Nitrogen[b]	13,500[a]	14,355	15,815	15,743	15,221
Phosphate[b,c]	8,800[a]	9,657	10,013	9,693	9,279
Potassium[b]	9,400[a]	10,233	11,300	10,888	10,228
Synthetic ammonia[d]	na	19,422	20,330	19,931	19,590
Plastics[e]	5,500[a]	5,763	5,675	5,488	5,345
Sodium hydroxide	3,000[a]	3,185	3,323	3,288	3,229
Ethylene	na	3,137	3,175	2,977	2,799
Methanol	na	3,331	3,211	3,284	3,219
Synthetic rubber[f]	na	2,400	2,435	2,366	2,320
Pesticides[g]	na	276	317	327	332
BULGARIA					
Sulfuric acid	na	846	840	688	807
Mineral fertilizers[b]	na	724	588	571	580
Nitrogen[b]	na	555	588	443	448
Phosphate[b]	na	169	179	128	132
Synthetic ammonia[d]	na	1,326	1,342	1,070	1,091
Plastics	231	328	363	322	420
Sodium hydroxide	na	118	124	104	138
Synthetic rubber	na	25	25	24	25
Pesticides[g]	na	19	18	15	15
CZECHOSLOVAKIA					
Sulfuric acid	1,033	1,142	1,249	1,264	1,292
Mineral fertilizers[b]	877	1,008	1,025	984	1,041
Nitrogen[b]	514	604	596	596	614
Phosphate[b,c]	257	296	313	277	307
Potassium[b,g]	106	108	116	111	120
Synthetic ammonia[d]	na	797	774	781	765
Plastics	1,174	1,186	1,192	1,150	1,140
Sodium hydroxide	335	337	337	332	335
Synthetic rubber	70	75	79	76	76
Pesticides[g]	17	18	19	18	20
HUNGARY					
Sulfuric acid	244	482	512	573	540
Mineral fertilizers[b]	693	903	921	1,067	1,040
Nitrogen[b]	419	587	574	667	655
Phosphate[b]	94	215	238	283	267
Potassium[b,h]	180	101	136	117	118
Synthetic ammonia[d]	576[f]	681	691	784	763
Plastics	603	638	590	545	426
Sodium hydroxide[i]	193	204	202	201	202
Ethylene	234	262	264	270	269
Pesticides[g]	24	38	35	38	35
POLAND					
Sulfuric acid	1850[f]	3114	3154	3149	2966
Mineral fertilizers[b]	1854	2725	2719	2622	2526
Nitrogen[b]	1302	1643	1622	1543	1445
Phosphate[b]	467	945	962	942	948
Potassium[b,h]	85	137	134	137	133
Synthetic ammonia[d]	1768[f]	1941	1923	1791	1747
Plastics	624	721	723	641	632
Sodium hydroxide	397	434	444	422	427
Ethylene	308	322	328	276	279
Methanol	155	162	168	172	169
Synthetic rubber	103	125	128	117	116
Pesticides[g]	na	11	11	9	8
ROMANIA					
Sulfuric acid	1112	1687	1825	1693	1971
Mineral fertilizers[b]	1742	2805	2994	2897	3278
Nitrogen[b]	1225[f]	2035	2130	2096	2315
Phosphate[b]	425[f]	648	725	665	849
Synthetic ammonia[d]	1974[f]	2744	2804	2784	3037
Plastics	520[f]	640	653	638	664
Sodium hydroxide	556	763	821	817	846
Ethylene	243	332	335	319	312
Synthetic rubber	102	149	161	152	173
Pesticides[g]	21[f]	34	39	39	47

a Approximate figures. b Nutrient content basis, as N, P_2O_5, or K_2O. c Including production of ground phosphate rock for direct applications and phosphate animal feeds. d Nitrogen content. e Including resins for man-made fibers. f Estimated. g On basis of active substance. h Imported potash added to domestically produced nitrogen and phosphate to form multinutrient fertilizer. i Including regenerated NaOH. na = not available. **Sources:** Central Intelligence Agency, Department of Agriculture, PlanEcon Inc., official national statistics from state central statistical bureaus

SOVIET FOREIGN TRADE: Rapidly rising trade deficit also affects chemical trade

$ Millions	1990[a]	1989[a]	1988	1987	1986	1985	1984	1983	1982	1981	1980
Exports[b]	$ 98,172	$109,299	$110,740	$107,664	$ 97,053	$87,196	$91,495	$91,652	$87,168	$ 79,380	$ 76,437
Imports[b]	114,372	114,698	107,316	95,971	88,874	83,315	80,409	80,445	77,846	73,194	68,473
Trade balance	−16,200	−5,399	3,424	11,693	8,179	3,881	11,086	11,207	9,322	6,186	7,964
Chemical exports[b]	na	3,592	3,559	2,979	2,770	2,837	2,707	2,307	2,203	2,275	2,025
Chemical imports[b]	na	5,404	4,924	4,516	3,990	3,744	3,256	3,216	3,028	3,211	3,275
Chemical trade balance	na	−1,812	−1,365	1,537	−1,220	−907	−549	−909	−825	−1,651	−1,250

a Preliminary values. b Free on board. na = not available. **Sources:** Central Intelligence Agency, U.S.-U.S.S.R. Trade & Economic Council, based on official Soviet statistics and exchange rates for the Soviet foreign exchange ruble

SOUTH KOREA

INDUSTRY TRENDS: Chemicals up strongly

Index, 1985 = 100	1990	1989	1988	1987	Change 1989–90
Chemicals, petroleum, coal, rubber, and plastic products					
Production	172.9	154.8	150.7	127.6	12%
Shipments	174.4	152.7	146.8	124.5	14
Inventories	176.1	155.4	128.6	114.2	13
Industrial chemicals					
Production	188.6	156.6	149.3	128.0	20
Shipments	184.7	151.6	146.1	128.2	22
Inventories	183.0	164.6	117.6	107.1	11
Other chemical products					
Production	205.5	183.0	171.3	133.1	12
Shipments	209.4	186.5	170.0	135.6	12
Inventories	234.6	195.5	159.5	121.7	20
Rubber products					
Production	144.7	128.1	151.1	140.1	13
Shipments	143.8	128.1	150.9	139.2	12
Inventories	122.3	123.1	131.2	119.4	−1
Plastic products					
Production	158.9	156.9	159.5	138.1	1
Shipments	151.2	145.5	148.3	133.4	4
Inventories	225.9	193.3	148.3	143.5	17
All manufacturing					
Production	186.5	171.3	166.3	146.6	9
Shipments	191.0	171.6	164.6	145.1	11
Inventories	190.7	162.1	137.6	120.7	18

Source: Korean National Statistical Office

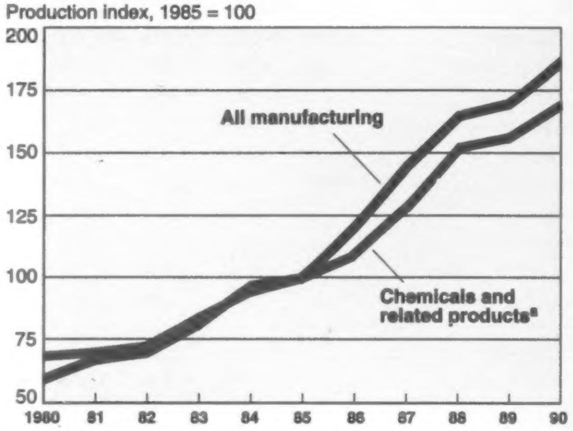
FOREIGN TRADE: Imports far outpace exports

$ Millions	1990	1989	1988	1987
Exports[a]	$ 65,016	$ 62,377	$ 60,696	$ 47,281
Imports[b]	69,844	61,465	51,811	41,020
Trade balance	−4,828	912	8,886	6,261
Chemical exports[a,c]	2,511	2,050	1,879	1,321
Chemical imports[b,c]	7,434	7,158	6,282	4,595
Chemical trade balance	−4,922	−5,108	−4,404	−3,274

a Free on board. b Includes cost, insurance, freight. c Includes chemicals and related products. **Source:** Korean Office of Customs Administration

Growth picks up in 1990 for South Korean chemicals production

Production index, 1985 = 100



a Includes petroleum, coal, rubber, and plastic products.
Source: Korean National Statistical Office

PRODUCTION: Organics post biggest gains

Thousands of metric tons	1990	1989	1988	1987	Change 1989–90
Complex fertilizers	1926	1985	2076	2026	−3%
Ethylene	1054	663	609	576	59
Urea fertilizers	883	888	1000	911	0
Polyethylene	786	637	572	469	23
Polyester fibers	730	654	593	496	12
Propylene	608	375	351	328	62
Polypropylene	574	530	518	348	8
Polyvinyl chloride	526	464	455	451	14
Polystyrene	507	434	341	304	17
Benzene	381	305	308	339	25
Synthetic detergents	342	297	278	214	15
Sodium hydroxide	328	295	311	262	11

Source: Korean National Statistical Office

AUSTRALIA

PRODUCTION: Plastics ease downward

Thousands of metric tons, unless otherwise noted	1990[a]	1989[a]	1988[a]	1987[a]	Change 1989–90
Chemicals					
Superphosphate[b]	2659	na[c]	na[c]	na[c]	—
Sulfuric acid, 100%	1464	1904	1818	1678	−23%
Ammonium sulfate	214	165	179	165	30
Acetylene, thousand cubic meters	2654	na[c]	na[c]	na[c]	—
Plastics and resins	975	986	990	904	−1
Detergents and soap	319	na[c]	na[c]	na[c]	—
Flexible plastic film, sheets[d]	183	na[c]	na[c]	na[c]	—
Polyethylene[e]	141	na[c]	na[c]	na[c]	—
Polypropylene	19	na[c]	na[c]	na[c]	—

a Year ending June 30. b Includes double and triple superphosphates expressed in terms of single phosphate (9% P equivalent). c Not available prior to July 1989 because of revised commodity classification. d Includes flexible plates, sheets, foil, and strip of plastics; excludes self-adhesive, floor, wall, and ceiling coverings, vulcanized fibers, plastic foam, and plastics reinforced, laminated, or supported with other materials. e Low and high density. na = not available. **Source:** Australian Bureau of Statistics

FOREIGN TRADE: Exports growing fastest

$ Millions	1990[a]	1989[a]	1988[a]	1987[a]
Exports[b]	$ 37,817	$ 35,465	$ 29,936	$ 23,745
Imports[c]	39,510	38,404	29,592	24,568
Trade balance	−1,693	−2,939	344	−823
Chemical exports[b]	948	861	650	440
Medicinal products	205	190	149	110
Chemical imports[c]	3,999	4,046	3,119	2,304
Organic chemicals[d]	825	951	806	584
Medicinal products	631	566	472	337
Chemical trade balance	−3,051	−3,185	−2,469	−1,864

Note: Monetary statistics converted from Australian to U.S. dollars on basis of $A1.00 equals: 1987, $0.6636; 1988, $0.7290; 1989, $0.8160; 1990, $0.7697. a Year ending June 30. b Free on board. c Values for customs purposes, free-on-board basis. d Includes organic-inorganic and heterocyclic compounds. **Sources:** Australian Department of Foreign Affairs & Trade, Reserve Bank of Australia

CHINA

PRODUCTION: Big gains for plastics, fibers, and especially soda ash

Thousands of metric tons	1990	1989	1988	1987	Change 1989–90
Synthetic ammonia	21,251	20,675	19,725	19,486	3%
Fertilizer[a]	19,120	18,547	17,670	17,033	3
Sulfuric acid[b]	11,689	11,408	10,981	9,620	2
Sodium hydroxide[b]	3,338	3,211	2,925	2,735	4
Sodium carbonate	3,746	2,983	2,593	2,372	26
Plastics	2,249	1,973	1,552	1,571	14

Thousands of metric tons	1990	1989	1988	1987	Change 1989–90
Man-made fibers	1625	1466	1284	1157	11%
Synthetic detergents	1484	1431	1290	1192	4
Ethylene	1572	1405	1231	839	12
Pesticides	229	224	202	157	2
Pharmaceuticals	172	196	194	154	−12
Synthetic rubber	316	289	251	218	9

a Nutrient content. b 100%. na = not available. **Sources:** State Statistical Bureau of the People's Republic of China, *China Economic News*, Central Intelligence Agency, *China Statistics Monthly*

CHEMICAL IMPORTS: Decline continues in 1990

$ Millions[a]	1990	1989	1988	1987	Change 1989–90
Organic chemicals	$1131	$1405	$1701	$ 998	−20%
Inorganic chemicals	215	469	448	422	−54
Dyeing, tanning, coloring materials	244	226	237	202	8
Medicinal and pharmaceutical products	395	311	384	229	27
Fertilizers[b]	2605	2364	2335	1399	10
Plastic materials, resins, cellulose esters and ethers	1498	2206	3558	1470	−32
TOTAL[c]	**$6650**	**$7556**	**$9139**	**$5008**	−12%

a Includes cost, insurance, and freight. b Manufactured. c For all chemicals and related products. **Source:** General Administration of Customs of the People's Republic of China

CHEMICAL EXPORTS: Growing strongly

$ Millions[a]	1990	1989	1988	1987	Change 1989–90
Organic chemicals	$ 838	$ 690	$ 575	$ 500	21%
Inorganic chemicals	842	794	762	553	6
Dyeing, tanning, coloring materials	366	288	229	175	27
Medicinal and pharmaceutical products	622	549	468	408	13
Essential oils, perfumes, cleansing materials	319	235	183	136	36
Explosives, pyrotechnic products	211	244	298	183	−13
TOTAL[b]	**$3730**	**$3201**	**$2897**	**$2235**	**16%**

a Free on board. b For all chemicals and related products. **Source:** General Administration of Customs of the People's Republic of China

TAIWAN

INDUSTRY TRENDS: Chemicals set the pace

Industrial production indexes, 1986 = 100	1990	1989	1988	1987	Change 1989–90
All manufacturing	117.3	119.3	115.4	111.2	−2%
Chemical materials	119.6	110.3	108.0	103.6	8
Basic chemicals	114.8	102.9	94.4	96.5	12
Petrochemicals	96.0	92.9	98.8	97.1	3
Fertilizers	114.1	111.3	113.4	102.9	3
Synthetic fibers	142.7	126.7	113.5	109.7	13
Plastics and resins	139.1	126.1	122.8	110.6	10
Chemical products	139.8	129.1	125.7	114.8	8

Source: Taiwan Ministry of Economic Affairs

FOREIGN TRADE: Chemical exports up 6%

$ Millions	1990	1989	1988	1987
Exports[a]	$ 67,214	$ 66,201	$ 60,585	$ 53,612
Imports[b]	54,716	52,249	49,656	34,957
Trade balance	12,498	13,952	10,929	18,655
Chemical exports[a,c]	5,711	5,397	4,844	3,741
Chemical imports[b,c]	7,621	7,408	7,051	5,150
Chemical trade balance	−1,910	−2,011	−2,207	−1,409

Note: Statistics converted from NT$ to U.S. dollars on basis of $1.00 equals: 1990, NT$26.9; 1989, NT$26.4; 1988, NT$28.6; 1987, NT$31.8. a Free on board. b Includes cost, insurance, and freight. c Includes chemicals, chemical products and plastic and rubber products. **Sources:** Taiwan Council for Economic Planning & Development, Taiwan Ministry of Finance Department of Statistics, C&EN estimates

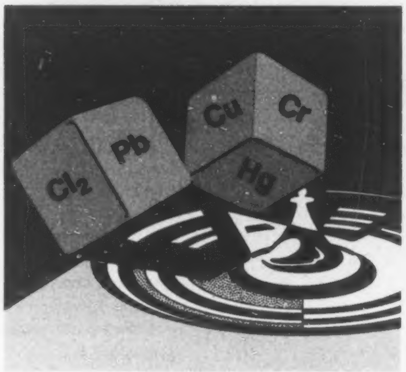
PRODUCTION: Many plastics doing well

Thousands of metric tons, unless otherwise noted	1990	1989	1988	1987	Change 1989–90
Polyester[a]	1290	1193	1100	1076	8%
Polyvinyl chloride	921	805	779	773	14
Terephthalic acid[b]	798	583	495	500	37
Ethylene	776	766	852	823	1
Vinyl chloride	665	662	708	699	0
Sulfuric acid	658	768	664	742	−14
Ammonium sulfate	509	524	484	485	−3
Propylene	398	398	441	442	0
Acrylonitrile-butadiene-styrene	384	311	301	208	23
Oxygen[c]	370	352	350	261	5
Polyethylene[d]	360	344	390	375	5
Styrene	355	301	331	310	18
Calcium superphosphate	354	352	315	342	1
Ammonia, anhydrous	263	246	339	296	7
Xylene	254	239	164	235	6
Paints	239	214	247	229	12
Hydrochloric acid	234	217	255	251	8
Urea	229	237	306	244	−3
Dioctyl lactam	188	179	167	192	5
Ethylene glycol	178	216	197	195	−18

a Filament and fiber. b Pure terephthalic acid. c Millions of cubic meters. d Low and high density. **Source:** Taiwan Council for Economic Planning & Development

Multiple Chemical Sensitivity

Reviewed by **Herbert L. Needleman**



Sensitivity to small doses of chemicals is a serious problem, and developing a sound database to sort it out will take a long time

"Chemical Exposures: Low Levels and High Stakes" by Nicholas A. Ashford and Claudia S. Miller, Van Nostrand Reinhold, 115 Fifth Ave., New York, N.Y., 10003, 1991, 214 pages, **$18.95**

In the closing months of World War II, with Hitler's Wermacht in wholesale retreat across Europe, a series of unusual advertisements by chemical, refrigerator, and automobile manufacturers began to appear in American magazines. These ads hoped to sell nothing; the sponsors' factories were busy supplying the Allied war effort. Their purpose was to refurbish the memories of potential customers for such names as Chevrolet, Norge, and Du Pont, and to prime the pump for the time when consumer goods instead of tanks and warplanes would roll off the production lines.

The prototypical advertisement portrayed a GI in a foxhole visualizing the glittering future (often a gauzy sketch in the upper right-hand corner) that waited for him at home. Gleaming glass skyscrapers laced by sweeping superhighways made up the cities of his vision. He was to have not just a car, but a personal helicopter, air-conditioning, wire recorders, 15-hour coast-to-coast air travel, and plastics! Four decades later, we have achieved almost all of this and much more. And now at the end of the 20th century, the motto "better living through chemistry" has a quaint and ironic ring.

Parallel with our society's simplistic, optimistic view of materialistic progress and the new chemical products that came with it, toxicologists in the 1940s relied almost entirely on the LD_{50} (lethal dose/50%) to test chemical toxicity. This is the measure of what dose kills half the rodents in a given experiment. But important changes in the health sciences began to emerge as the war came to an end. Toxicologists began to reduce their dependence on the LD_{50}. Slowly, and with no little resistance, attention shifted to subtler outcomes: growth rates, biochemical indexes, and even behavior. The threshold for toxicity dropped, the definition of specific toxic syndromes broadened, the number of individuals defined as affected increased, and the allowable exposure levels for many substances were reduced.

These more sensitive measures led some toxicologists and environmental scientists to realize that there were more affected individuals at lesser exposures than we had previously reckoned. We began to get hints that each synthetic process bears its own risk or cost and that these clever synthetic molecules eventually find receptors or targets in human beings.

Blue-collar workers are among the first to be affected. They encounter the highest doses in their workplaces, but they are not the only individuals to be exposed. Sealing a building allows biologically active vapors to pile up, and these affect white-collar employees as well. Glues, caulks, plasticizers, and pesticides can be irritating to almost everybody and are downright sickening to some.

A growing number of people display recurring symptoms in many organ systems that appear related to very small doses of a number of chemicals. Perhaps 15% of individuals experience increased sensitivity to multiple chemicals and the number may be growing.

This is a serious problem. And it is vexed, as are most serious problems, by at least three competing interest groups, each with a different viewpoint. The orthodoxy is represented by clinical allergists, and the heterodoxy by clinical ecologists, a relatively new but large group. Clinical ecology developed in reaction to the refractory approach of orthodox allergists to any "sensitivity" phenomenon not accompanied by evidence of humoral allergy exhibited in a positive serum or skin test. Clinical ecologists are a growing and vocal group with about 2000 practitioners. The third interest group is psychiatrists, who often are asked to see patients with obscure and ill-characterized complaints. Psychiatrists have tended to view this turmoil from Olympian heights and assign the label of malingerer, hysteric, or depressive to the victim.

Into this intellectual-tag team match come Nicholas A. Ashford and Claudia S. Miller with their book "Chemical Exposures: Low Levels and High Stakes." It takes no small amount of courage to enter a field as roiled as this, and the authors are to be commended for their attempt to bring the light of scholarship and the scalpel of criticism to bear. They are partially successful. Even though this is a new field, the relevant literature is huge, and this

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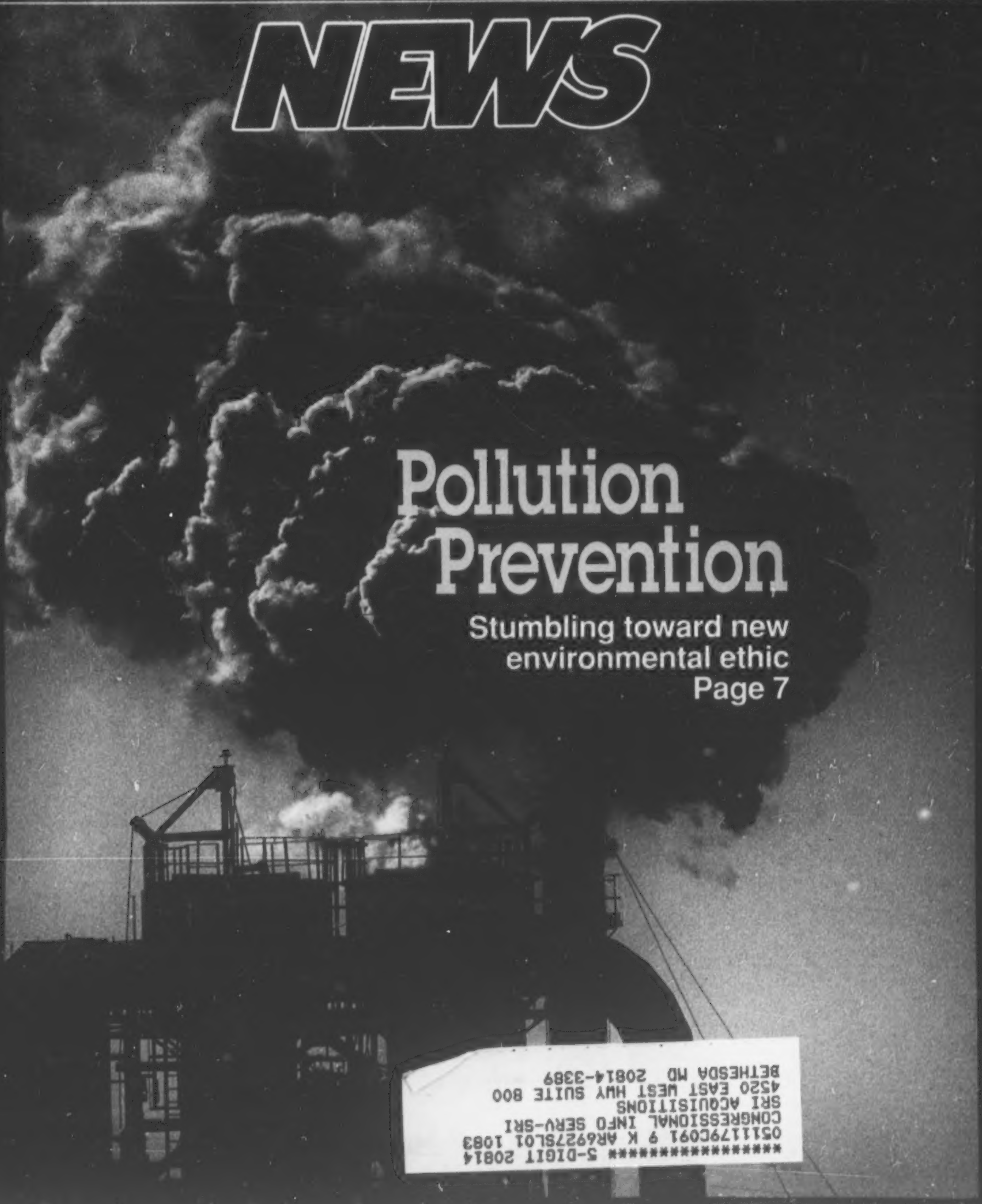
JULY 8, 1991
CHEMICAL & ENGINEERING
NEWS



Pollution Prevention

Stumbling toward new environmental ethic
Page 7

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Volume 69, Number 27
CENEAR 69 (27) 1–58
ISSN 0009-2347

CHEMICAL & ENGINEERING
NEWS
JULY 8, 1991

News of the Week

- **Financial observers look for improvement in Allied-Signal's earnings as Lawrence A. Bossidy takes over as chief executive officer.** Page 4
- **Canadian scientists develop new approach to oligosaccharide synthesis that may lead to automated technique.** Page 5
- **Monsanto launches huge restructuring program that will consolidate its chemical businesses, reduce work force by 2500 worldwide.** Page 5
- **Forensic chemist has exposed a scheme by drug dealers to smuggle cocaine by compounding it with polystyrene, molding the resin into plastic parts, and then recovering the cocaine by extraction after import into the U.S.** Page 6
- **Second round of discussions on an international treaty to protect global climate ended with very little progress.** Page 6

Cover: Photo by Gerard Fritz/Uniphoto Picture Agency

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Business

Fertilizer production moved up again, but only a few percent, in the just completed crop year, and likely will grow about the same in the new crop year. **Page 21**

Waste plastic is viewed as attractive source of profits by Resource Recycling Technologies, a New York-based waste recycler. **Page 23**

Mexico still faces shortages of basic petrochemicals, lacks needed investment funds despite policy reforms aimed at attracting foreign participation. **Page 24**

Government

House completes work on fiscal 1992 appropriations bills, providing 18% increases for NSF and for EPA R&D but funding the space station by freezing spending for NASA. **Page 27**

Science/Technology

European Community urged to work at commercializing results of its science research programs. **Page 33**

Computational fluid dynamics set to become routine design tool for process engineers. **Page 34**

New test promises to detect individual's exposure to AIDS virus as much as a year before current tests can detect infection with the virus. **Page 35**

News Focus

Pollution prevention rather than pollution control is becoming preeminent as public, private groups join forces to curb emissions at the source. **Page 7**

Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
Robert H. Marks, Director, Publications Division

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Subscription Rates 1991: Printed editions: nonmembers U.S. 1 yr. $95, 2 yr. $171; outside U.S. 1 yr. $131, 2 yr. $243. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $12. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management: CENTCOM LTD.
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LETTERS

Make a positive change

The letter by Mark C. Piton (C&EN, May 13, page 4) was encouraging and refreshingly positive. I am tired of reading and hearing the innumerable complaints of the problems caused by an ill-informed public. Complaining does not help. We need to redirect this negative energy into positive pursuits. I feel it is our responsibility as chemists, the chemically informed public, to do what we can individually to improve our image in the eyes of our respective communities.

I have taken Piton's advice, and would like to share a few experiences from my part of the world. This past year I have participated in a program called "Chemistry Is Fun" sponsored by the chemical company where I am employed. All of the approximately 50 participants are free to design their own program of chemical demonstrations. The programs are designed to show young people, grades three through 12, that chemistry is fun and that it surrounds them in their everyday lives. I prefer grades three to five. These kids are energetic, curious, and eager to learn. The greatest challenge I face is to explain each demonstration in terms simple enough for the students to understand.

I always start out by asking them to share what comes to mind when they think about chemistry. The terms shared most often (sadly but not surprisingly) are explosions, dangerous, nerds, mad scientists, fires, accidents, and so on. Often I am asked to "make something blow up." Of course, I try to dispel these fears. Encouragingly, however, they are very concerned to know what I will be doing with the wastes generated during the demonstrations. Will I bury it in a landfill? Will I clean out and reuse the sample bottles? Explaining our policy of incineration, I am questioned about the possibility of toxic emissions from the burning process. I am encouraged to see this awareness among the young children. When I was their age, I didn't think about these issues. I am excited about the potential of the upcoming generation, but they need to be properly educated to make informed decisions for their future. I am not stressing that they should all become chemists, just that they have a fundamental understanding so that they will be more responsible citizens.

There is so much we can teach these children. I always include an experiment with a foamed polystyrene cup. I am able to explain that it is not a "styrofoam" cup, the name commonly used even among the chemical community. Styrofoam is the trademark for the insulation (blue) made by Dow Chemical for the construction industry. I begin by holding up a regular white foamed polystyrene cup and ask the class to identify it. When they respond by calling it a styrofoam cup, I correct them before proceeding with the experiment. I show them that polystyrene is soluble in methylene chloride but will precipitate by the subsequent addition of methanol. This naturally leads us to a discussion on recycling, another subject of concern and interest to them.

I am amazed that on several occasions the children have expressed genuine surprise to see a female chemist. As a result, I am especially eager to encourage the girls to follow their interests and to ignore any lower expectations that may sometimes be placed on them. One principal asked us to "encourage the girls because some of them are afraid to take math and science." In a civilized society such as ours, this should not be the case; this must change. We, the chemical community, can provide positive role models for these young women and men.

I urge you all to do what you can within you own area and your circle of influence. If we all work together, we can make a difference. We can make a positive change.

Virginia A. Dais
Midland, Mich.

Corrections

- April 29, page 21: Coauthors of the paper on the liquid membrane flue-gas cleanup system, besides Soung S. Kim, Department of Energy's Pittsburgh Energy Technology Center, were S. Majumdar, J. S. Cha, T. Papadopoulos, and K. K. Sirkar of the department of chemistry and chemical engineering, Stevens Institute of Technology.
- June 17, page 48: The technical program summary for the combined chemical congress and ACS national meeting in August lists two symposia on biopolymers offered by the Analytical Chemistry Division. The full title for the symposium listed as "chromatography of biopolymers" is "Preparative/Process Chromatography of Biopolymers." It will be held all day on Tuesday, Aug. 27. The other biopolymer symposium, "Rapid Biopolymer Characterization," will be held on Friday morning, Aug. 30.

House Doesn't Tarry in Completing Work on Agency R&D Funding Bills

None lose and many gain, with NSF and EPA support up 18%, but funding for space station *Freedom* is at expense of other NASA programs

Janice R. Long, C&EN Washington

The House, moving at a near record pace, completed its work on all of the fiscal 1992 appropriations bills that fund the government's research and development activities before lawmakers headed home for the July 4 recess. The Senate will work its will after the recess.

The House provided increases of well over 15% for research programs at the National Science Foundation and the Environmental Protection Agency. Total funding for Department of Energy research programs is up 12%, while the National Institutes of Health and the Department of Agriculture had to settle for 7% increases.

Less fortunate were the research activities of the departments of Defense and Commerce, for both of which the House approved 3% increases. And the National Aeronautics & Space Administration's research budget is frozen at its current level.

The full House made very few, mostly minor, changes in the bills that were reported out of the House Committee on Appropriations. The one exception was a major change in H.R. 2519, the departments of Veterans Affairs and Housing & Urban Development and Independent Agencies Appropriations Bill, which provides funds for NASA.

The Appropriations Committee refused to fund the $1.93 billion request for space station *Freedom* on the grounds that other higher priority programs needed the money that would be freed up by suspending the program for the time being. That decision allowed the committee to provide funding increases for all of NASA's other research programs, while cutting overall research funding 14% from current levels to $5.2 billion in fiscal 1992.

However, the full House overturned that decision, voting to continue funding for the space station by freezing spending for all NASA programs at fiscal 1991 levels.

> **What's happening to basic energy sciences in fiscal '92 may be a harbinger of what's to come for other programs**

The House did not overturn the committee's decision not to fund NSF's new $50 million academic research instrumentation program. The committee explained that it had denied the funds "without prejudice on the basis of a lower overall priority and in view of the exceptionally tight budget limitations facing all domestic discretionary programs."

One obviously higher priority for the committee was NSF's academic research facilities modernization program, which the Administration had decided not to fund in fiscal 1992. The committee rejected that decision, providing $20 million for the program, $478,000 less than is being spent on it this year.

Another high priority with both the committee and the Administration is NSF's science education programs. The Administration had asked for a 21% increase to $390 million for these programs. It got a 35%, $113 million, increase to $435 million. Out of that increase, $25 million is earmarked for a new graduate traineeship program with funds allocated on a competitive basis directly to recipient institutions, and $13 million is earmarked for "summer institutes" associated with NSF teacher preparation and teacher enhancement programs.

For NIH the House approved an overall fiscal 1992 funding level of $8.8 billion, with the individual institutes receiving increases ranging from 6 to 12%. Fiscal 1992 is one of the rare years in which the House did not provide a lot more money for NIH than had been requested by the Administration, coming in just 1% over the $8.7 billion request. In fact, the Appropriations Committee took Bush's 1992 budget submission with the largest increase ever presented by a President for NIH as a hopeful sign that Congress and the Administration were in general agreement on the need for stability and predictability in NIH's budget.

The committee said, however, that it "has been greatly disturbed, as has the general public, with recent publicity regarding abuses by certain institutions in claiming reimbursements for costs under the indirect cost recovery system." It went on to say that it is concerned that these specific cases, "as offensive as they are," may merely be superficial signs of a systemic problem with the whole federal research grant system.

The committee endorsed the Office of Management & Budget's 26% cap on a wide range of indirect administrative costs, which is expected

House backs Administration on need for more R&D funds

$ Millions	1992 Appropriation	1992 Request	1991	% difference Appropriation-request	% change 1991–92
Defense	$36,949.5	$38,921.0	$35,722.3	−5%	3%
Air Force	14,263.9	15,032.6	11,961.3	−5	19
Defense agencies	8,979.1	10,238.5	9,115.7	−12	−2
Navy	7,464.9	7,342.6	9,237.9	2	−19
Army	6,241.6	6,307.3	5,607.4	−1	−11
NIH[a]	8,824.9	8,737.3	8,239.0	1	7
Cancer	1,830.5	1,772.6	1,676.5	3	9
Heart, Lung & Blood	1,202.4	1,209.9	1,126.9	−1	7
Allergy & Infectious Diseases	972.8	976.7	907.3	0	7
General Medical Sciences	820.2	833.2	760.0	−2	8
Diabetes & Digestive & Kidney Diseases	667.8	658.6	615.3	1	8
Neurological Diseases & Stroke	583.4	583.4	541.7	0	8
Child Health & Human Development	524.7	520.6	478.9	1	10
Aging	362.5	348.6	323.7	4	12
Eye	272.3	272.3	253.2	0	7
Environmental Health Sciences	254.9	254.5	241.0	0	6
Arthritis & Musculoskeletal & Skin Diseases	205.0	204.8	193.2	0	6
Dental Research	161.2	160.9	148.9	0	8
Deafness & Other Communicative Disorders	144.5	146.3	134.9	−1	7
Other	822.7	794.9	837.5	3	−2
Energy R&D	6,263.4	5,984.0	5,604.0	5	12
Energy supply	2,854.0	2,821.4	2,527.1	1	13
General science and research	1,405.5	1,548.9	1,148.7	−9	22
Weapons	1,275.6	1,262.6	1,254.9	1	2
Fossil	454.0	77.0	458.7	490	−1
Conservation	274.3	274.1	214.6	0	28
NASA R&D	6,023.6	7,198.5	6,023.6	−16	0
NSF	2,643.5	2,643.5	2,238.0	0	18
Research and related activities	1,960.5	1,963.5	1,694.2	0	16
Education and human resources	435.0	390.0	322.3	11	35
Antarctic research	118.0	118.0	100.0	0	18
Salaries & expenses	110.0	122.0	101.0	−10	9
Academic research facilities	20.0	0	20.5	100	0
Academic research instrumentation	0	50.0	0	−100	0
USDA	1,306.9	1,256.5	1,221.2	4	7
Agricultural Research Service	710.4	709.2	665.1	0	7
Cooperative State Research Service	412.9	384.1	388.5	7	6
Forest research	183.6	163.2	167.6	12	9
EPA R&D	512.4	491.5	433.7	4	18
Commerce	461.4	460.6	447.6	0	3
NIST	237.6	248.0	216.3	−4	10
NOAA	223.8	212.6	232.3	5	−4
TOTAL	$62,985.6	$65,692.9	$59,929.4	−4%	5%

Note: All numbers are estimates. a Includes AIDS research and research training. **Source:** House Appropriations Committee reports

to save NIH $55 million next year, as an "effective first step." The next step, according to the committee, must deal directly with the broad area of facilities renovation and replacement in a thoughtful way. In another area, the committee asked whether it was "unreasonable to ask a peer review panel to advise NIH whether a project is technically sound, important to biomedical science, fiscally reasonable, and deserving of support with public funds."

At DOE, funding for basic energy sciences is increased less than 1% to $715 million, the amount requested by the Administration. Within that total, funding for chemical sciences is essentially frozen at $158 million, and funding for materials sciences is down 7% to $257 million. One major difference between DOE's fiscal 1992 appropriations bill and those approved by Congress in previous years is that it is not littered with funds earmarked for specific projects at various academic institutions.

What's happening to basic energy sciences in fiscal 1992 may be a harbinger of what is to come for other research programs. In a number of its reports on the 13 appropriations bills, the committee made some reference to the fact that it is not possible to fund 10 to 15% increases for all federal domestic discretionary agencies when total growth permitted by the 1991 Budget Summit Agreement is less than 7.5%. "The simple truth," according to the committee, "is that unless the Administration is willing to either increase revenues or curtail nondomestic discretionary spending, this nation's human, technical, and physical infrastructure will continue to erode."

The crunch has already hit at DOD. Its programs are allowed to grow by just about 4% under the 1990 budget agreement. The 3% increase allowed for DOD research programs by the House is below even that target. Funding for DOD's technology base programs—essentially basic research—fares even worse; it is essentially frozen at $3.9 billion, 5% less than the request. Funding for the Strategic Defense Initiative is down 7% to $2.7 billion, 46% less than the Administration had wanted. □

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JULY 15, 1991

CHEMICAL & ENGINEERING NEWS

Scientists present latest in
AIDS research at Florence conference
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Salary & Employment Survey

Recession raises joblessness
among chemists, as salaries
make routine gains
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CENEAR 69 (28) 1–60
ISSN 0009-2347

CHEMICAL & ENGINEERING NEWS

JULY 15, 1991

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- **Chemical companies tally and tout their progress in cutting toxic air emissions; Monsanto's ambitious efforts draw praise from EPA.** Page 7
- **Senate panel votes to fund space station *Freedom*, despite last-minute appeal by coalition of scientific societies.** Page 7
- **Single-molecule gates that control access to electrodes offer new possibilities for molecular recognition and selectivity in electrochemistry.** Page 8
- **Former East Germany's chemical industry can be saved only by rapid privatization, billion-dollar investments, and drastic work force reductions, according to study by German agency Treuhandanstalt.** Page 8

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News Focus

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Work on a comprehensive energy bill has started in Congress but likely won't be finished before year's end. **Page 26**

Legislation to expand the toxic chemicals list covered under Superfund right-to-know provisions is being readied in the Senate. **Page 28**

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NIST's advanced technology program is seeking proposals for generic technologies projects. **Page 33**

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"The Chemical Industry in the U.S.S.R.: Economic Geography" is long-needed reference work with historical perspective. **Page 40**

Salary Survey

Current recession has taken its toll on chemists, boosting joblessness significantly higher to 1.6%, ACS survey shows. Median salaries are up 4.4%, just about in line with inflation. **Page 35**

Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
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Subscription Rates 1991: Printed editions: nonmembers U.S. 1 yr. $95, 2 yr. $171; outside U.S. 1 yr. $131, 2 yr. $243. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $12. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Business with Burma

Myanmar, known as Burma until June 1989, is an underdeveloped country rich in natural resources, although it has not always been this way. Prior to 1962, Burma was one of Southeast Asia's most progressive countries economically, socially, and educationally. It is home to the world's largest and most pristine teak forests, unmined gold, and sizable oil reserves.

From 1962 until today Burma has been closed to the outside world. After September 1988, most countries providing assistance to Burma suspended their aid (both humanitarian and nonhumanitarian). With the advent of widespread international condemnation of the actions of the Burmese government, many companies have since entered into business relationships with Burma. Why? What provoked so many nations of the world (including the U.S., Canada, U.K., and Japan) to severely curtail or eliminate assistance programs with Burma? Yet why are so many companies now engaged in dealings with Burma, a trend inconsistent with the majority of the international community? Finally, what concern is any of this to the members of the American Chemical Society in particular, and the chemical community in general?

In order to gain an understanding of what's at stake, one needs merely to take a glimpse at Burma's contemporary political and social situation. After 25 years of repressive military rule, a prodemocracy movement achieved widespread support and called for free and fair elections, the restoration of civil and political liberties, and an end to constitutional dictatorship. In August 1988 a nationwide peaceful demonstration was held only to be met with large-scale killings of demonstrators by the Burmese Army. At least 3000 students, civilians, and Buddhist monks were killed by the Army during the summer of 1988.

Outraged by the military's blatant disregard for human rights, the international community suspended assistance programs with Burma. Facing a financial crisis due to the abrupt withdrawal of aid from foreign governments, the Burmese government began selling rights to foreign companies for on-shore oil exploration. Despite the denouncement of Burma's human rights violations by many nations, several companies from around the world signed contracts with Burma's military government—including Amoco and Unocal from the U.S. and government-owned Petro-Canada (despite the Canadian government's official denouncement of Burma's human rights violations).

Under burgeoning public pressure, the military government announced that parliamentary elections would be held in May 1990. To the government's astonishment and dismay, the people of Burma voted the military government out of power (democratic representatives won over 80% of the Parliament seats). Despite the unambiguous election results, the military refused to hand over rule to the newly elected representatives. A large number of representatives were arrested and imprisoned. Recently, the military junta signed a $1 billion arms deal with China, a pact that is said to include chemical weapons (an allegation Burma staunchly denies). Meanwhile, Burma's colleges remain closed and most children are denied an education. Human rights violations continue by the hundreds, as does condemnation by most governments of the world. Thus, it appears that petrochemical investments strengthen the position of Burma's military regime without benefiting the general population.

Petrochemical companies are among the most publicly visible elements of the chemical community and, indeed, the business community worldwide. Chemists and chemical engineers already suffer from a dismal public image due, in no small part, to environmental disasters

Corrections

- June 24, page 4: The chemicals used to produce Antiblaze 19, a flame retardant manufactured at the Albright & Wilson Americas plant where an explosion occurred, are trimethyl phosphite, dimethyl methylphosphonate (DMMP), and trimethylolpropane (TMOP) or 2-ethyl-2-(hydroxymethyl)-1,3-propanediol. TMOP was incorrectly identified as trimethyl phosphate.
- June 24, page 84: The base allotment for local sections in 1992 will be $3020, not $3030, resulting in a total allotment for all sections in 1992 of $1,013,600, instead of the reported figure of $1,017,472.

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Recession Raises Joblessness Among Chemists, Salaries Post Routine Gains

Latest annual ACS survey shows 1.6% of respondents were unemployed earlier this year and salaries have risen to median of $52,000

Michael Heylin, C&EN Washington

The 1991 annual salary and employment survey of ACS members confirms the considerable impact the current recession has had on the job market for chemists. On March 1 this year, the date of the survey, 1.6% of respondents were jobless. This was significantly higher than the 1.0 to 1.1% level of the previous four years. It was the highest level of chemists unemployed, but seeking employment, since 1986, when it was 1.7%. More than 40% of those unemployed on March 1 had been jobless for more than six months.

The new survey also indicates that salaries for the chemistry profession overall advanced to a median of $52,000 for those working full time. This was up 4.4% from the $49,800 median for the 1990 survey. As in recent years, this gain was just about in line with inflation. The consumer price index for wage earners rose 4.6% between March 1990 and March 1991. Individual chemists, who all gained an extra year of experience and some of whom earned promotions between the two surveys, did better. They apparently posted an average salary gain of somewhat more than 6% for the year.

The median salary is that which is exceeded by 50% of survey respondents. It is used because it is not affected by a few extremely high or low cases and so more accurately reflects the typical salary than does the mean. All salaries quoted in this article are for chemists employed full time. They represent the base annual salary from a chemist's principal job.

This year's survey involved sending questionnaires to a random sample of 17,000 ACS members living in the U.S. who were not more than 70 years old and neither students nor on retired status. The survey was conducted by ACS's Market & Business Analysis Department under the direction of senior research analyst Joan Burrelli.

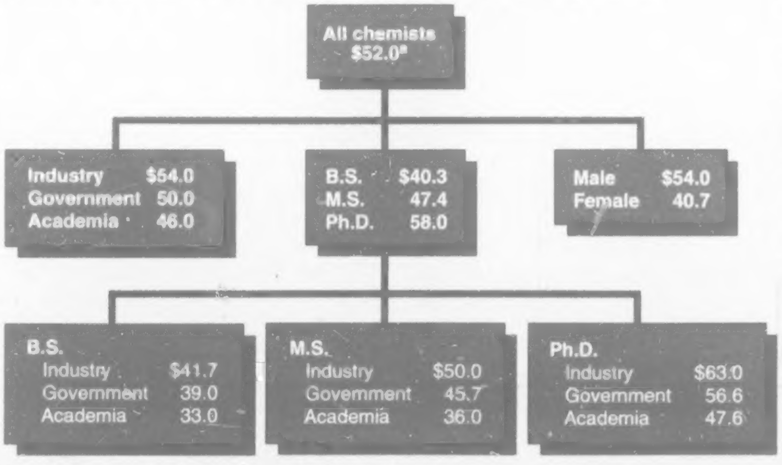
More than 9800 questionnaires were returned for a 58% response rate. Of those who responded, 56% held doctoral degrees, 19% had master's degrees, and 24% had bachelor's degrees. By race, 88.5% were white, 7.8% Asian, 1.6% Hispanic, 1.2% black, 0.4% American Indian, and 0.5% "other." By sex, 82% were men, 18% women. By employment, 62% worked for industry, 25% were academics, and 13% worked for government or in other nonacademic positions.

As has usually been the case, the unemployment rate for chemists has apparently remained markedly below other indexes of joblessness. This was certainly true of the 1.6% rate indicated for chemists in the latest survey. The unemployment rate for all civilian workers was at 6.8% in March this year, up from 5.3% a year earlier. Of those with a managerial or professional specialty, 2.5% were unemployed this March, up from 1.8% in March 1990.

It is not known how precisely the unemployment data obtained from these surveys of ACS members measure the level of joblessness throughout the chemical profession. However, year-to-year changes in the unemployment rates obtained from the surveys are at least strong qualitative indicators of shifts in the job situation for chemists.

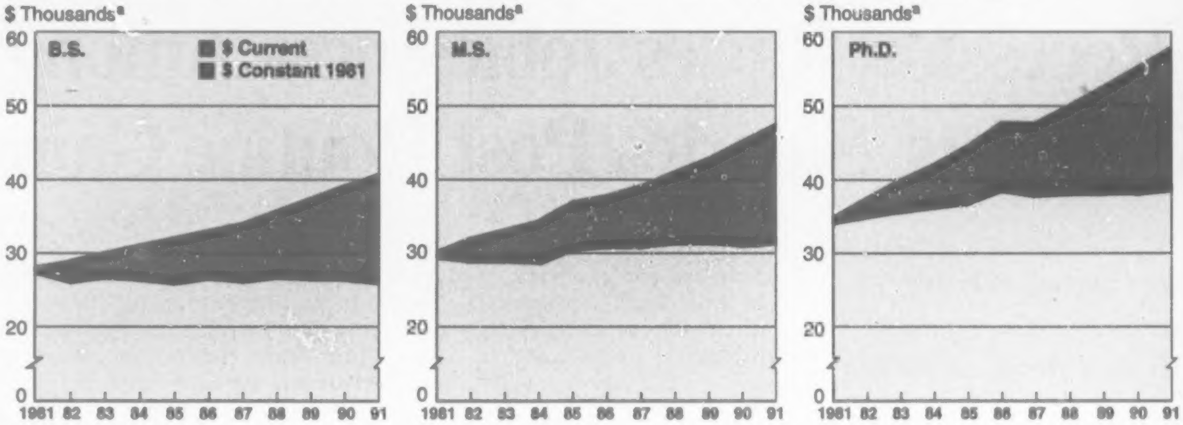
The jobless rate from the surveys hovers close to 1.0% during healthy economic times. It reached 2.2% in the recession year of 1983 and peaked at 3.2% during the more seri-

Male Ph.D. industrial chemists top the salary scale



a Median base annual salaries in thousands of dollars as of March 1, 1991. Source: ACS survey

Median salaries for Ph.D. chemists have risen faster than for their B.S. colleagues



Note: Average salary increases for individual chemists have been larger because of increasing experience. a Median base annual salary for chemists employed full time as of March 1 of each year. **Source:** ACS survey

Median salary of all chemists exceeds $50,000 for first time

$ Thousands	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	Annual change 1990–91	Annual change 1986–91	Annual change 1981–91
CHEMISTS' MEDIAN SALARIES[a]														
B.S.	$40.3	$39.0	$37.0	$35.4	$33.5	$33.0	$32.0	$30.9	$30.0	$28.5	$27.5	3.3%	4.1%	3.9%
M.S.	47.4	45.0	43.0	41.0	39.0	37.9	36.0	34.0	33.0	31.6	30.0	5.3	4.6	4.7
Ph.D.	58.0	55.0	52.5	50.0	47.7	47.8	44.0	42.0	40.0	37.5	35.0	5.5	3.9	5.2
All chemists	52.0	49.8	47.3	45.0	42.5	42.5	40.0	38.0	36.0	34.7	32.0	4.4	4.1	5.0

a Base annual salary of chemists employed full time as of March 1. **Source:** ACS survey

Women chemists' salaries average about 88% those of male counterparts

Mean salary, $ thousands[a]	B.S. All chemists	B.S. Men	B.S. Women	B.S. Women as % of men	M.S. All chemists	M.S. Men	M.S. Women	M.S. Women as % of men	Ph.D. All chemists	Ph.D. Men	Ph.D. Women	Ph.D. Women as % of men
EMPLOYER												
Private industry	$46.5	$50.2	$40.3	80%	$54.2	$56.2	$50.1	89%	$68.6	$69.8	$65.7	94%
Academic	31.0	32.7	30.1	92	36.3	39.2	32.8	84	52.2	53.9	44.2	82
Government	40.3	42.9	39.1	91	46.8	48.2	43.7	91	59.4	61.1	51.9	85
Other	51.3	57.3	37.8	66	47.2	49.9	42.5	85	66.8	70.0	51.5	74

a As of March 1, 1991; to facilitate comparison, women's salaries are adjusted for the difference in average length of experience between them and men. **Source:** ACS survey

ous economic downturn for the chemical profession in 1972. The surge to 1.6% this year reflects the current less severe recession. Industrial chemists apparently have been the most vulnerable to joblessness lately, at 1.8% according to the latest survey, and academics the least, at 0.9%.

By recent job function, former general managers were the most likely to be unemployed, 2.4% as of this March, according to the survey. Teachers were the least likely, 0.7%. Research workers, at 1.5%, were just about at the 1.6% overall median.

Slow economic times also bring increases in both postdoctoral ranks and the number of chemists working part time. This is reflected in the latest survey. Chemists on postdocs or fellowships moved up to 2.6% of the total from a year-earlier 2.2%, and part time employees increased to 1.8% from 1.4%.

Women are particularly vulnerable to this trend in relatively hard times. For instance, the latest survey indicated that 4.2% of women chemists were employed part time, but only 1.2% of men worked part time. Women also were overrepresented in the postdoctoral ranks—3.0% compared with 2.5% for men. Overall, about 91% of women chemists were employed full time compared with about 95% of the men.

During the 12 months covered by the latest survey, 3.1% of chemists were unemployed at one time or another. Slightly more than half of them found new jobs within three

Years of experience is the major determinant of salary level

Median salary, $ thousands[a]	Years since B.S. degree 2 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39	40 or more	Overall median
ALL CHEMISTS [a]	$30.1	$38.0	$47.5	$52.0	$58.0	$61.0	$60.7	$64.0	$66.0	$52.0
By sex										
Male	32.0	40.0	48.2	53.3	60.0	63.0	62.3	66.1	66.7	54.0
Female	29.6	36.0	42.7	45.0	46.0	45.0	50.0	42.6	49.0	40.7
By degree										
Bachelor's	30.0	35.0	42.0	46.6	50.7	51.5	52.0	60.0	59.0	40.3
Master's	—	37.0	44.9	49.6	52.0	49.4	53.2	55.0	62.5	47.4
Doctor's	—	47.0	51.0	56.0	61.3	65.0	65.5	68.0	69.9	58.0
By employer										
Industry	31.0	40.0	50.0	56.0	62.3	68.3	70.0	73.8	68.0	54.0
Government	—	35.0	40.6	45.7	52.4	55.5	56.3	57.5	—	50.0
Academia	—	31.6	37.0	40.0	43.4	48.1	54.1	54.6	60.7	46.0

a As of March 1, 1991. **Source:** ACS survey

months. But one fifth were unemployed for more than six months. Most affected were women chemists, 5.2%, and B.S. chemists, 4.5%. These figures were little changed from 1990 survey data.

This year's questionnaire asked chemists if they thought they are underemployed. Twenty-two percent responded yes. The range was from 18% for Ph.D.s to 28% for B.S. chemists. Of those who agreed they are underemployed, about half indicated they would prefer a more challenging position. Others noted their current position was not commensurate with their training or experience. About 7% of all respondents indicated they were looking for a new position.

The salary data in the new survey confirm once again what has been known for a long time—that the biggest single determinant of chemists' salaries is experience. Other critical factors are degree level, type of employer, managerial role, and gender.

To illustrate the importance of experience, in the 1991 survey the median salary for senior chemists from 30 to 34 years beyond their B.S. was $60,700. This was 60% higher than the median of $38,000 for chemists 25 years their junior with just five to nine years beyond their undergraduate degree. This large differential is partly due to the substantially higher percentage of Ph.D.s in the older group, 67%, than in the younger, 36%.

In industry managers have clear salary advantage

Median salary, $ thousands	By degree B.S.	M.S.	Ph.D.
R&D management	$60.3	$65.0	$76.1
General management	53.7	62.0	78.0
Marketing	43.2	53.8	64.5
Applied research	42.0	48.4	58.0
Production	38.0	46.0	56.0
Basic research	36.0	44.7	60.0

a As of March 1, 1991. **Source:** ACS survey

However, even within the same degree level the salary differential for the 25 years of extra experience is still very substantial—around 45%. For B.S. chemists in the two groups the difference is 49%, $52,000 compared with $35,000. For M.S. chemists the difference is 44%. For Ph.D.s it is 39%.

For most of their careers, Ph.D. chemists earn between about 20 and 25% more than their B.S. colleagues of the same age. The median salary for all Ph.D.s is $58,000, some 44% higher than the $40,300 median for B.S. chemists. This extra differential is largely due to the dominance of chemists with Ph.D.s in the higher paid, older groups.

In the 1991 survey, B.S. chemists represent only 12% of those 35 to 39 years beyond their undergraduate degree. This compares with 46% of the five-to-nine year group, and reflects the fact that older B.S. chemists are more likely to leave ACS than are their Ph.D. colleagues. However, older B.S. chemists who do retain their society membership apparently do quite well, with median salaries within about 15% of those of their Ph.D. contemporaries for the closing years of their careers.

Full professors at Ph.D.-granting schools average $80,000

Median salary, $ thousands[a]	9–10 month contracts Non-Ph.D. school	9–10 month contracts Ph.D. school	11–12 month contracts Non-Ph.D. School	11–12 month contracts Ph.D. school
Full professor	$47.2	$60.0	$69.6	$80.0
Associate professor	36.8	44.4	54.4	53.0
Assistant professor	31.5	36.0	40.0	42.9

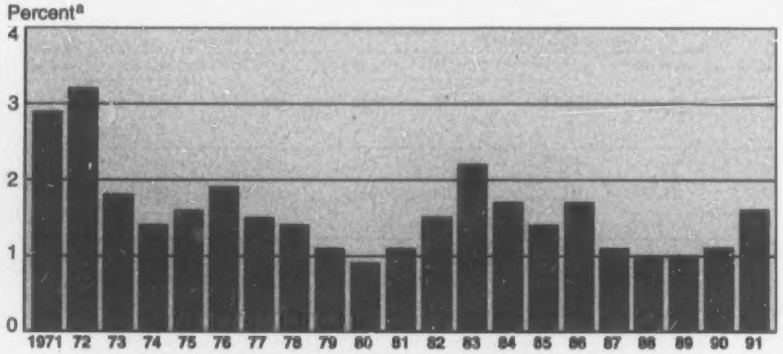
a As of March 1, 1991. **Source:** ACS survey

Chemists augment salaries with other income

$ Thousands	Salary[a]	Other[a,b]	Total[a]
B.S.	$40.3	$1.7	$42.0
M.S.	47.4	1.1	48.5
Ph.D.	58.0	2.0	60.0
All chemists	52.0	1.5	53.5

a Median value as of March 1, 1991. b Includes only other professional income. **Source:** ACS survey

Chemists' unemployment still below earlier recessions



a Unemployed, but seeking employment, as of March 1 each year. **Source:** ACS survey

Industrial chemists apparently have a salary advantage over their colleagues in academia. Despite the fact that relatively fewer industrially employed chemists are Ph.D.s, about 50% compared with about 90% of academics, the 1991 survey indicates a median salary for industrial chemists of $54,000, considerably higher than the $46,000 median for academics. Government chemists fall right between at $50,000. However, it has to be remembered that more than 60% of academics are on nine- or 10-month salary contracts and are often able to augment their income during the summer months.

Those that reach the top of the academic profession—full professors—receive competitive salaries. The median for full professors on 11- or 12-month contracts at Ph.D.-granting institutions is $80,000. At non-Ph.D.-granting institutions it is $69,600. These salaries are about 80% higher than those for assistant professors.

For chemistry faculty members who are on nine- or 10-month contracts, salaries are, as would be expected, substantially lower. For full professors at Ph.D.-granting schools the median is $60,000; at non-Ph.D. schools it is $47,200. Assistant professors on such shorter contracts post a median salary of $36,000 at graduate schools and $31,500 at non-Ph.D.-granting institutions.

In industry the bigger salaries are in management. For instance, Ph.D.s working in general management had a median salary of $78,000 in the latest survey. For those in R&D management it was $76,100. These salaries compare with medians of $56,000 for Ph.D.s in production, and $58,000 for those in applied research.

Industrial chemists are at highest job risk

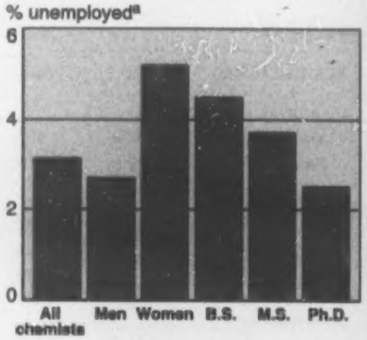
	% of chemists in category	% unemployed[a]
MOST RECENT EMPLOYER		
Industry	62%	1.8%
Academia	25	0.9
Government	8	1.2
Other	5	1.8
MOST RECENT WORK FUNCTION		
R&D	42%	1.5%
Teaching	12	0.7
R&D management	11	1.6
General management	8	2.4
Production	6	1.4
Other	16	1.6

a As of March 1, 1991; excludes chemists who are unemployed but are not seeking employment. **Source:** ACS survey

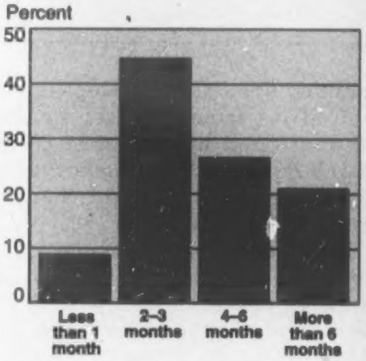
This advantage for those in management persists at other degree levels. For instance, M.S. chemists in R&D management have a median salary of $65,000, well above the $46,000 for M.S. chemists in production. Similarly, B.S.-level R&D managers' median salary of $60,000 is 67% higher than the $36,000 median for B.S.-level industrial chemists in basic research.

The median salary for male chemists in the 1991 survey is $54,000. This is 33% higher than the $40,700 median for their female colleagues. A significant part of this difference reflects the reality that, as a group, male chemists are older, more experienced, and more likely to hold an advanced degree.

3% of chemists were jobless sometime last year . . .



. . . almost half of them for more than three months



a Excludes chemists who were not employed but not seeking employment. **Source:** ACS survey

However, substantial differences persist even when salaries are compared within degree levels and after allowance is made for the shorter experience of women. Burrelli has undertaken this analysis, calculating the mean salaries, by degree, for men and women in industry, government, and academia. On this basis, most women earn between 80 and 94% as much as their male counterparts. The overall average is about 88%. This situation has changed very little in recent years, except that today starting salaries for men and women with equal qualifications are essentially the same.

According to Burrelli, geographic location is not a major determinant of chemists' salaries. For instance, salaries for industrially employed Ph.D.s 10 to 14 years beyond their B.S. cluster closely between $50,000 and $53,000 throughout the country.

Some chemists supplement their salaries with other professional in-

Percentage of chemists employed full time at lowest level in seven years

Employment status[a]	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981
Employed full time	94.0%	95.2%	95.3%	95.4%	95.4%	94.8%	95.2%	93.7%	93.5%	94.9%	95.6%
Employed part time	1.8	1.4	1.5	1.6	1.5	1.5	1.5	1.7	1.7	1.4	1.1
Postdoctoral or fellowship	2.6	2.2	2.2	2.0	2.0	2.0	1.9	2.9	2.6	2.2	2.2
Unemployed	1.6	1.1	1.0	1.0	1.1	1.7	1.4	1.7	2.2	1.5	1.1

[a] As of March 1, 1991; excludes chemists who are not employed but not seeking employment. **Source:** ACS survey

Women and B.S. chemists more likely to be among the unemployed

	Chemists									
		By sex		By highest degree			By minority status		Chemical engineers
Employment status[a]	Total	Men	Women	B.S.	M.S.	Ph.D.	Minority[b]	Nonminority	
Employed full time	92.6%	93.5%	88.9%	93.5%	94.2%	91.9%	88.2%	93.2%	94.7%
Employed part time	1.8	1.2	4.2	2.1	2.0	1.5	0.6	1.9	0.9
Postdoctoral or fellowship	2.6	2.5	3.0	0.1	0.1	4.3	8.0	1.9	0.7
Unemployed									
Seeking employment	1.6	1.5	1.9	2.0	1.7	1.3	2.5	1.4	1.3
Not seeking employment	1.5	1.3	2.0	2.2	2.0	1.0	0.7	1.5	2.4

[a] As of March 1, 1991. [b] Black, Spanish/Hispanic, American Indian, Alaskan native, Asian, Pacific Islander, or other. **Source:** ACS survey

come, but generally to a modest degree. For all chemists the median of such extra income is $1500 per year—somewhat less for government chemists, somewhat more for academics. For M.S. and Ph.D. academics the median is closer to $4000. Such supplemental income includes consulting fees, bonuses, earnings from a second job, overtime, and income from summer teaching.

ACS's salary surveys do not directly measure average year-to-year salary changes for individual chemists. The surveys are based on random samples of ACS membership, not the same sample every year, and the questionnaire asks only the salary as of March 1 of the current year. It does not also ask what the salary was one year earlier.

The surveys measure the increase in salaries throughout the profession year-to-year. But they do not measure the salary profile of individuals as they move up through the profession gaining experience and, in many cases, increasing responsibilities.

To illustrate the point, the 1981 survey indicated that B.S. chemists 10 to 14 years beyond their graduation then received a median salary of $27,000. In the 1991 survey, B.S. chemists with this amount of experience received a median salary of $42,000. This represented a 4.5% average annual gain over the 10 years, more or less in line with inflation. However, by 1991 those who had been in the 10- to 14-year group in 1981 had moved to the 20- to 24-year group in 1991 with a median salary of $50,700, for a 6.5% average annual gain for the decade.

As another example, in the 1981 survey, Ph.D. chemists 10 to 14 years beyond their B.S. posted a median salary of $30,000. By the 1991 survey this cohort had moved to the 20- to 24-year group with a median salary of $61,300. This represented a 104% increase over the decade for an average annual gain of 7.4%.

This type of analysis indicates that over the past decade, when the cost of living has increased an average of a little more than 4% per year, B.S. and M.S. chemists have posted annual salary gains that have varied from about 8% for those early in their careers to about 5% for their older colleagues. For Ph.D.s the gains have clustered more closely in the 6 to 7% range with less variation with age.

The latest annual salary survey of the membership of the National Society of Professional Engineers also brings out this difference between the rate of growth of salaries professionwide and of individual salaries. In this survey respondents were asked to provide both their current salary, as of Jan. 1 in this case, and the size of any salary increase during the previous year. Survey data indicate the median income of all engineers rose 2.7%, from $55,500 to $57,000, for the year. However, engineers who had not changed jobs and who had not been promoted received an average salary increase of 5.7%.

The 1991 survey asked academics what they did with their working time. Fifty-five percent indicated they spend half or more of it teaching, 37% devoted their time primarily to research, and 8% spent half or more of their time on administration. Only 18% indicated they spend less than a quarter of their time teaching.

A complete presentation of the data from this year's ACS survey, "Salaries 1991," will be available next month at a price of $150 per copy. It can be purchased from the ACS Distribution Office, Room 210, American Chemical Society, 1155—16th St., N.W., Washington, D.C. 20036. Questions or comments on the survey should be directed to Joan Burrelli at (202) 872-4433. □

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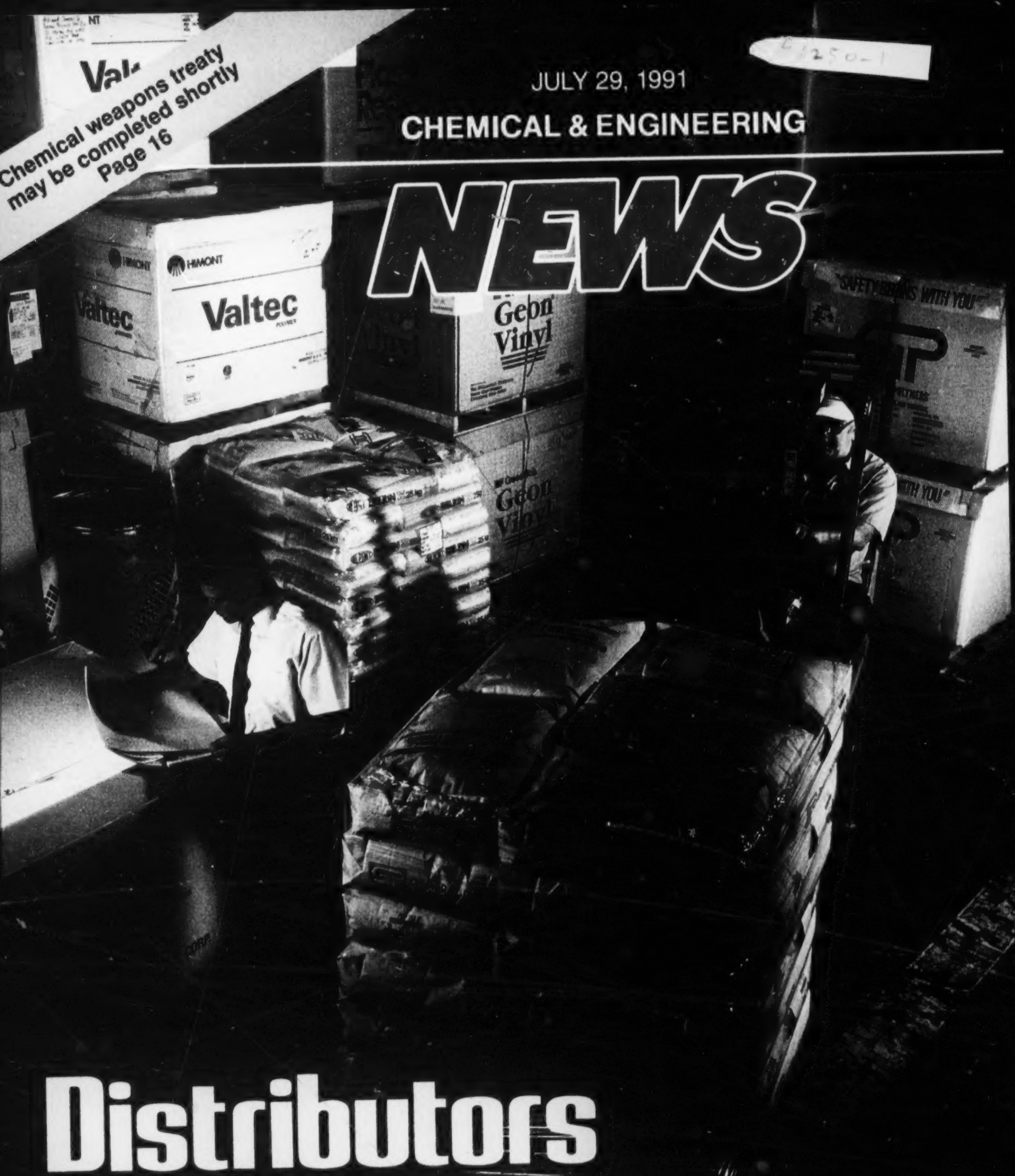
JULY 29, 1991

CHEMICAL & ENGINEERING NEWS

Chemical weapons treaty may be completed shortly
Page 16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A growing role in chemical industry
Page 25

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CHEMICAL & ENGINEERING
NEWS

Volume 69, Number 30
CENEAR 69 (30) 1-76
ISSN 0009-2347

JULY 29, 1991

News of the Week

- **New NIH director Bernadine Healy outlines long-range strategic plan that would sharply boost the number of grants the agency awards.** Page 6
- **Du Pont has launched a major program aimed at cutting annual costs by at least $1 billion over the next few years.** Page 7
- **Tankcar derailment that poured 13,000 gal of soil sterilant metham-sodium into the Sacramento River likely will catalyze reform of safety regulations for rail shipment of toxic chemicals.** Page 7
- **Chiron and Cetus will combine to form a major biopharmaceutical firm, to be called Chiron Corp., in biggest merger between two biotech companies to date.** Page 8

Cover: Employee at Ashland Chemical's general polymers facility in Columbus, Ohio, checks shipments of resins

Business

Mexican state-owned Pemex will need creative financing to support its ambitious petrochemical expansion plans. **Page 13**

Government

Optimism is high for a chemical weapons treaty in 1992 as the result of the President's recent pullback of two U.S. positions that had been big stumbling blocks in the negotiations. **Page 16**

Science/Technology

Water-displacing quinone-amine polymers that were little noticed for years are being looked at anew for coating uses. **Page 20**

Nalco demonstrates its mobile lab designed for on-site water analysis, process simulation, and pilot testing. **Page 22**

ACS News

The new governing board for Chemical Abstracts Service and the background and reasoning behind its establishment are explained by ACS board chairman Joseph A. Dixon. **Page 45**

Meetings

Deadlines and topics for ACS meetings from spring 1992 in San Francisco through the year 2001 are listed. **Page 53**

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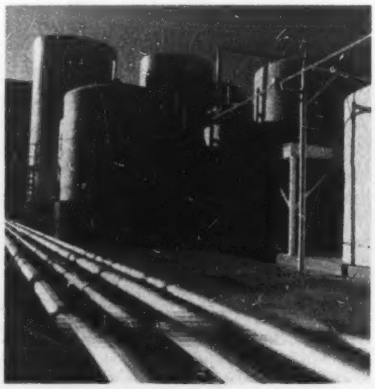

Product Report

Role of chemical distributors is growing in response to industry pressure for extra services such as sales and technical expertise and additional safety and environmental responsibilities for shipments. **Page 25**

Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036
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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
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Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

CHEMICAL SAFETY

Explosion of CO absorbent solution

For monitoring carbon monoxide in lime kiln gas, a solution of cuprous chloride was prepared by dissolving 53 g of cupric chloride dihydrate ($CuCl_2 \cdot 2H_2O$) in 300 mL of concentrated hydrochloric acid. The solution thus prepared was allowed to stand over 75 g copper turnings in a stoppered bottle.

Over a period of several days, the initially observed dark solution became completely colorless. Over the following weeks, a very small quantity of colorless solid, presumably Cu_2Cl_2, was observed to crystallize gradually on the bottom. On vigorous shaking, the crystals resisted going back in solution, thus reflecting a degree of saturation of a highly insoluble chemical under the conditions.

After several months this mixture reportedly exploded one night. The explosion was not witnessed but heard as a pop or shattering of glass, and later contents of the bottle were observed on the floor of the storeroom where the bottle was initially placed on a shelf. A dense fog, typical of hydrogen chloride in damp air, was noticed a few minutes later, but no smell of chlorine was reported.

The unanticipated explosion of an aqueous Cu_2Cl_2 solution has left me puzzled. Some senior colleagues from the American Chemical Society also seem to have no explanation. I would therefore appreciate hearing readers' comments.

Ihsan U. Shah
Holly Sugar Corp.
Stockton, Calif.

Help for Romanian chemists

Having had recent personal contacts within academic circles in Romania, we wish to draw attention to the situation of Romanian chemists and chemical engineers. In addition to the political and economic difficulties confronting all Eastern European countries in their transition to market economy, Romania has to heal the wounds inflicted by 25 years of dictatorship by the Ceaușescus. For chemists, this means lack of documentation (books and journals—especially those published during the past 15 years—and access to data banks), computer hardware and software, and modern equipment such as spectrometers (FT-NMR, FTIR, x-ray diffractometers), reprographic equipment, telefax, and the like.

Western European countries, and, more recently, the U.S., have initiated valuable aid campaigns for orphans and handicapped persons, but little has been done for Romanian scientists and students. Although not handicapped physically, these individuals are at a serious disadvantage owing to the situation described above. Thus, chemists in universities and research institutes, 18 months after the Romanian revolution, still lack funds in convertible currency that would enable them to bridge this gap.

We wish to make western chemists aware that donations that would fill the gaps would be of enormous benefit to Romanian students, teaching staff, and researchers.

Interested individuals who wish to donate books, journals, computers, or equipment should contact a freight for-

Corrections

- June 3, page 12: In 1990, the estimated U.S. market for phosphates in the food industry was 320 million lb. The reported figure of 67 million lb is the amount of phosphorus used in producing derivatives for the U.S. food industry.
- July 8, page 15: Methylene chloride, not methyl chloride, is being replaced by *N*-methyl-2-pyrrolidone for such uses as paint stripping and metal degreasing.
- July 15, page 9: The crystal structure of the HIV regulatory protein Tat has not yet been solved; numerous research groups currently are working on this problem.

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Pemex's Petrochemical Expansion Will Require Creative Financing

Mexican state-owned firm is not allowed to form joint ventures with private firms but could offer product instead of equity to investors

Earl V. Anderson,
C&EN Northeast News Bureau

Pemex, says one observer of the Mexican petrochemical scene, has plenty of plans—but very little money. That's little different than any number of large petrochemical companies scattered throughout the world today.

But there is a difference. Pemex is Petróleos Mexicanos, the oil and petrochemical monopoly owned by the Mexican government. Under the Mexican constitution, only Pemex can produce oil, natural gas, and the "primary," or basic, petrochemicals that feed the downstream petrochemical plants in Mexico.

This means Pemex cannot court private companies, Mexican or foreign, with joint-venture proposals to help finance costly petrochemical projects. And financial institutions seem reluctant to make conventional loans to Pemex for its petrochemical operations.

It is not that Pemex—the company—is not creditworthy. Based on its oil operations, it is probably the most creditworthy company in Mexico. But petrochemicals are another story. Pemex has earned a poor reputation in its petrochemical operations, a reputation that it is working hard to correct. Meanwhile, taxes and social programs that Pemex's oil earnings support leave precious little money available for much-needed petrochemical investment.

"We have a serious financial problem," says Antonio Juarez Alvarado, petrochemical coordinator for Pemex's relatively new petrochemical division. Thus Pemex is looking at what Juarez calls novel financing arrangements to help build at least $1.5 billion worth of petrochemical plants in the very near future.

By novel, he means using money from private Mexican or foreign companies to help build the plants. These companies, however, get no equity in the plants. Instead, they are paid with product after the plant is built and put on stream.

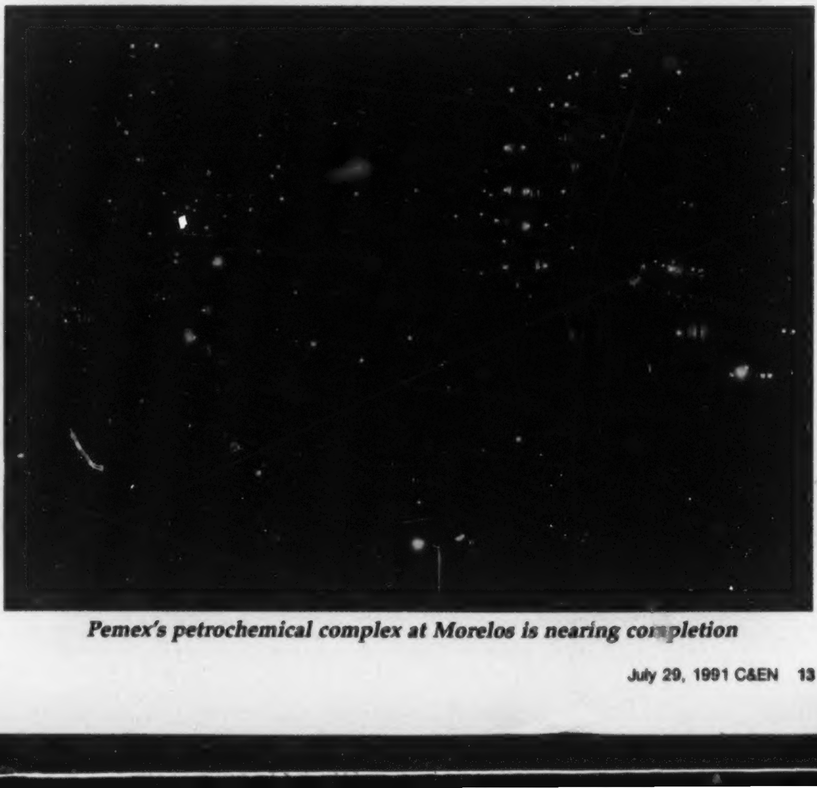
Pemex already has used this approach to finish two plants at its Morelos petrochemical complex that were running way behind schedule. Last year, Celulosa y Derivados S.A. (Cydsa) provided Pemex with about $10 million to finish its 50,000 metric-ton-per-year acrylonitrile plant at Morelos. The plant began operating early this year.

With its new Morelos unit, Pemex now has 180,000 metric tons of acrylonitrile capacity. With that, says Juarez, Pemex can supply the entire Mexican market and have some left over for export. Last year, the company produced 122,000 metric tons of acrylonitrile.

The same financing approach was also used to finish an acetaldehyde plant, also at Morelos. For this unit, about $15 million came from Celanese Mexicana, which will be repaid in product. This 150,000 metric-ton-per-year unit started up in December 1990.

Pemex, Juarez says, hopes to use this same novel financing scheme to help it build even more petrochemical plants. First, Pemex wants to finish its much-delayed propylene plant at Morelos.

Earlier this year, the company started operating the country's first polypropylene plant—a 100,000 met-



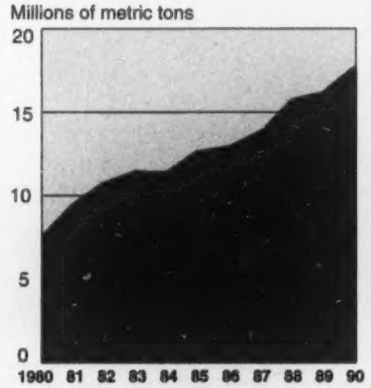
Pemex's petrochemical complex at Morelos is nearing completion ric-ton-per-year unit—at Morelos. But, until last year, Pemex had been importing between 13,000 and 20,000 metric tons of propylene every year. That's why finishing the 350,000 metric ton propylene unit at Morelos is so important. Juarez says that it will be finished by the end of next year, at a cost of about $100 million.

Also high on the priority list is an aromatics train, which Pemex plans to build at its Cadereyta refinery. This will be a huge project. Minimum annual capacities include 140,000 metric tons of benzene, 400,000 metric tons of *p*-xylene, 18,500 metric tons of toluene, 54,000 metric tons of mixed xylenes, and 41,000 metric tons of *o*-xylene. Adding in the auxiliary units that accompany an aromatics complex means Pemex probably is looking at a minimum investment of $600 million.

Another high-priority, and high-priced, project Pemex is considering is an additional ethylene plant. The plant, which the company plans to build in the state of Tabasco, will have a capacity of 500,000 metric tons per year and will cost an estimated $450 million, says Juarez.

Also under consideration is a methyl *tert*-butyl ether (MTBE) plant. Pemex had considered several options, including several small MTBE units, and perhaps a TAME (*tert*-amyl methyl ether) unit. Now the company is leaning toward one large MTBE plant that also would be built in the state of Tabasco and cost about $350 million.

Pemex's petrochemical output keeps climbing



Source: Pemex (Petróleos Mexicanos)

Output soars for most key chemicals in 10 years

Thousands of metric tons	Pemex production 1980	1990
Acetaldehyde	48	190
Acrylonitrile	54	122
Ammonia	1883	2632
Benzene	79	320
Butadiene	17	21
Carbon black	na	252
Cumene	0	53
Cyclohexane	40	75
Dichloroethane	106	394
Dodecylbenzene	55	117
Ethylbenzene	29	192
Ethylene	366	1370
Ethylene oxide	30	265
Methanol	174	210
Perchloroethane	0	12
Polyethylene, high density	67	176
Polyethylene, low density	91	348
Propylene	137	363
Propylene tetramer	36	98
Styrene	31	158
Toluene	125	368
Vinyl chloride	62	231
Xylene, mixed	77	404
o-Xylene	16	75
p-Xylene	39	226

na = not available. **Source:** Pemex (Petróleos Mexicanos)

In addition, it is considering a 60,000 metric-ton-per-year MTBE plant at Morelos, which Pemex "may try to build soon," says Juarez. Feedstock isobutylene already is available at Morelos, he notes.

Nobody questions the need for these projects. For instance, Pemex stopped importing huge volumes of *p*-xylene in 1987. But secondary petrochemical companies in Mexico—the companies that are Pemex's customers—imported almost 122,000 metric tons of the material last year. There are many similar examples.

What experts on the Mexican petrochemical industry do question is Pemex's ability to attract outside capital to finance these projects. They concede, however, that Pemex was able to do so for its acetaldehyde and acrylonitrile plants at Morelos.

But the money involved, says one former Pemex petrochemical official, was "small potatoes." For the projects that Pemex hopes to build, he adds, the costs jump "into the hundreds of millions [of dollars]."

Few outside Pemex believe that many Mexican—or foreign—companies will be interested in financing Pemex's huge petrochemical projects with repayment coming only as product. Pemex has had negotiations along these lines with, among others, Japanese, U.S., and European firms.

Nothing, however, has materialized yet. Some think nothing ever will. Nevertheless, Juarez says Pemex is "very close" to reaching a financing agreement for the aromatics project with a French company. And it is talking with other European companies about financing the ethylene plant.

Most observers agree that potential investors would be interested in financing the Pemex projects only if they received equity in the projects. Under current Mexican law, this is impossible.

What may be possible is that the "rules" of the petrochemical game in Mexico could be changed. Over the years, the long list of "primary" petrochemicals that were reserved solely for Pemex has been pared to only 19 products. The most recent to be removed and placed on the "secondary" petrochemical list was MTBE. Foreign companies can own up to 40% of operations producing products on this list (and, in some special cases, 100%).

Merely thinking along these lines will not make it happen. But even its detractors concede that Pemex is changing for the better, as far as petrochemicals are concerned.

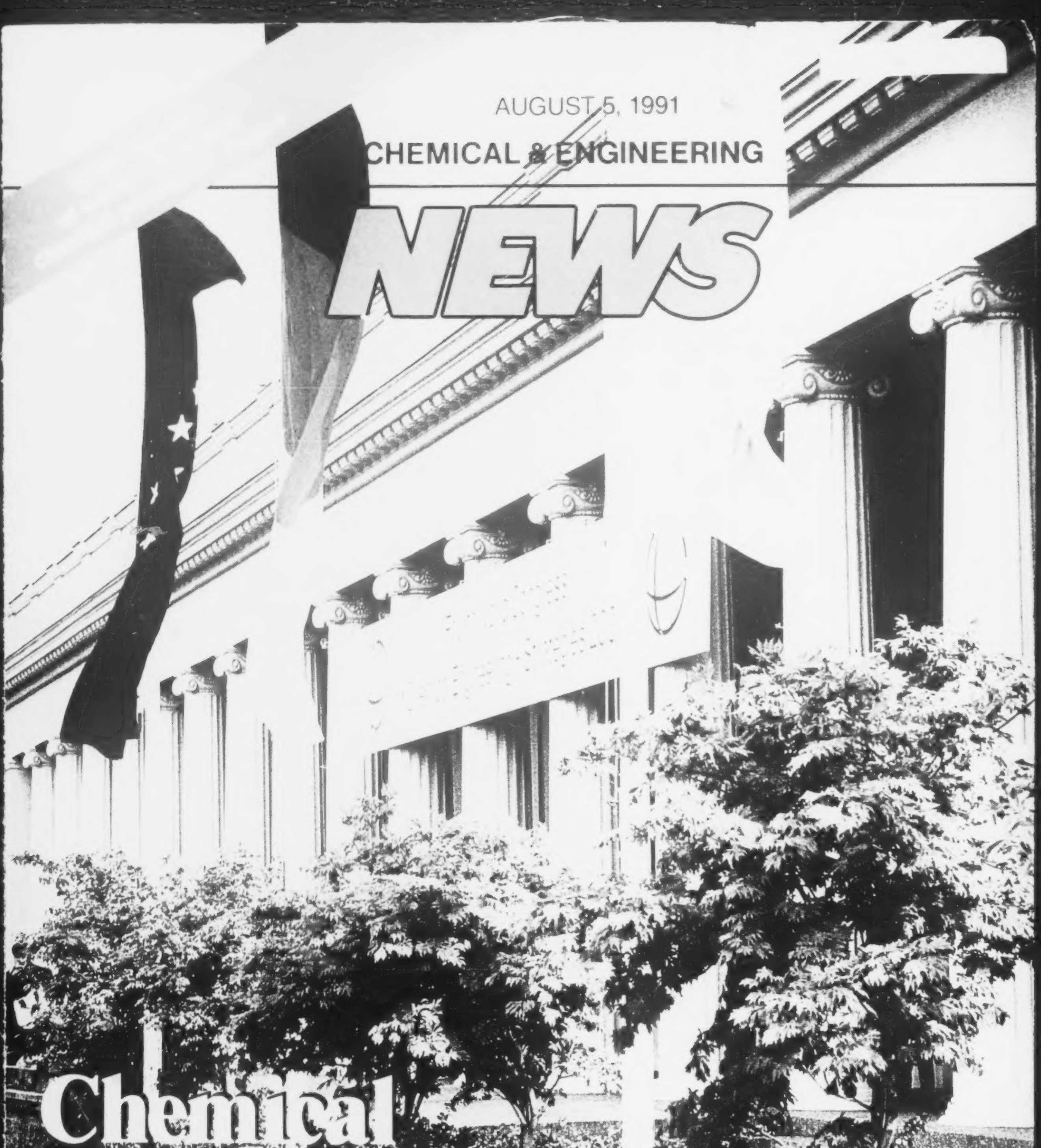
Last year, it created a separate petrochemical division to give petrochemicals more autonomy. Both Pemex and the country are committed to an open, market-oriented economy. The free trade talks with the U.S. and Canada testify to that. And there's almost universal agreement that Mexico needs foreign petrochemical investment.

Juarez says that Pemex is working hard to become a "world class" petrochemical company. It's a slow, difficult process because it means changing a philosophy that's deeply entrenched within the company. But, he adds, "we think we are starting to make our point." □

AUGUST 5, 1991

CHEMICAL & ENGINEERING

NEWS



Chemical Engineering

World congress reflects influ
of global concerns Pag

CHEMICAL & ENGINEERING NEWS

Volume 69, Number 31
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ISSN 0009-2347

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- **Contract workers in petrochemical industry are less experienced, less well trained, and are more likely to suffer accidents than regular employees, says OSHA-commissioned study.** Page 5
- **UN inspectors visiting Iraq's largest chemical weapons facility at Samarra uncover four times more weapons and chemical agents than Iraq declared.** Page 5
- **House subcommittee assails University of California for mismanagement and waste in its operation of two national labs for the Department of Energy.** Page 6
- **Researchers at University of California devise simple, general method for growing molecular materials in highly oriented form on Teflon-coated glass.** Page 6

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ACS News

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Cover: Photo by C&EN's James Krieger

Science/Technology

4th World Congress of Chemical Engineering, held this summer in Karlsruhe, Germany, portrays a discipline that is responding at many technical levels to worldwide concerns, including energy, the environment, plant safety, and product quality. **Page 16**

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Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036
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Published by
AMERICAN CHEMICAL SOCIETY
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Subscription Rates 1991: Printed editions: nonmembers U.S. 1 yr. $95, 2 yr. $171, outside U.S. 1 yr. $131, 2 yr. $243. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $12. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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(For list of offices see page 43)
Office of Ombudsman: (800) ACS-5558, No. 8

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Canadian GST Reg. No. R127571347

LETTERS

Perfluorocarbons

The featured letter under the title "Chemical Safety" (C&EN, June 10, page 2) asks suppliers to "heighten users' awareness of the reactivity of perfluorocarbons with oxidizers." The letter states that when a substrate was being oxidized "in a supposedly inert perfluorocarbon liquid," considerably more energy was released than anticipated. The letter also refers to conversations with knowledgeable coworkers who "indicated that perfluorinated organic compounds are more reactive with oxidizers—particularly oxygen gas—than is widely believed." No data are given and no proof is given that the perfluorocarbon was indeed involved.

These statements should be considered along with almost 50 years of experience of saturated perfluorocarbons and chloroperfluorocarbons in oxygen and other oxidizing service without any reports of exothermic reactions. These materials, when subjected to ASTM G72-82 "Standard Test Method for Autogenous Ignition Temperature of Liquids and Solids in a High-Pressure Oxygen-Enriched Environment," do not ignite throughout the entire test range, reaching over 400 °C in the presence of 2000 psig of oxygen.

It appears that before any recommendations in the safety letter on perfluorinated organic compounds are implemented, significantly more information is needed.

Louis L. Ferstandig
Vice President and Technical Director
Halocarbon Products Corp.
River Edge, N.J.

High school chemistry teachers

I was most pleased to read Michael P. Doyle's ACS Comment, "Value of high school chemistry teachers" (C&EN, May 20, page 31). The society has advanced rapidly in its understanding and actions regarding these teachers. In earlier times, high school chemistry teachers were allowed full membership in ACS only if their application was endorsed by two Ph.D. chemist members of ACS; and the *Journal of Chemical Education* was the only resource available to them through the Division of Chemical Education. This division continues to be incorporated separately from ACS with almost informal ties to the parent organization. Since the initiation of the ChemCom (high school chemistry program) by W. Thomas Lippincott and Sylvia Ware in 1981, and the subsequent appointment of Ware to the position of education director for ACS, the society has initiated a number of services useful both to high school chemistry teachers and to other teachers of school science.

Because there were so many earlier years of neglect by ACS for the professional needs of high school chemistry teachers, some ACS sections developed somewhat independent chemistry teacher affiliates. The Philadelphia and North Jersey sections, for example, offer "affiliate teachers" professional meetings, science days, newsletters, and so forth. The ACS education office does service these affiliates, only when requested, with newsletters such as *ChemMatters* and *Chemunity*. The local affiliate dues remain with each local affiliate.

Even with the best of intentions by ACS at the national level to better serve the needs of teachers of chemistry at the high school level, past history dictates that simply and bluntly offering a reduced dues structure will not increase regular membership substantially. Historical practice has developed somewhat of an ACS foster parent relationship for these teachers. Regular membership now, at a reduced dues rate, would not offer membership services beyond those available presently through the affiliate structure at a rate far below the national dues level. Put another way, competing forces already are in operation.

To enhance the profession of chemistry through service to high school chemistry teachers, the objective of the ACS Committee on Membership Affairs would be met best by placing the following plan into action:

1. Support the expansion of the existing Chemistry Teacher Affiliate groups.

Correction

• June 17, page 16: The work on control of ionization by laser interference was reported in *J. Chem. Phys.*, **94,** 8622 (1991), not page 2640.

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German Firms Continue To Dominate Global Top 50 Chemical Producers

World's top 50 chemical producers garnered a 6% sales increase in 1990 to $319 billion as profit margins fell, often to less than 10%

Patricia L. Layman, C&EN London

The U.S. has more large chemical producers than any other nation, although that number has fallen slightly since 1989. For any single region, however, Europe is home to the largest block of producers, and those companies dominate worldwide chemical sales.

Those are the two major conclusions from the second annual C&EN ranking of the world's 50 largest chemical producers. The ranking uses the same criteria as those used for the 100 largest U.S. chemical producers (C&EN, May 6, page 11). Thus, wherever possible, it excludes formulated products, such as coatings and pharmaceuticals, and specialty equipment, energy, and other nonchemical operations.

The total sales rung up by the 50 companies in 1990 were $319 billion, a 6% increase over their total 1989 sales. Nearly one fifth—$61.8 billion—of the total was accounted for by Germany alone, which has five companies in the top 50, including three in the first five.

The U.S. continued to account for the largest number of companies in the ranking—16. This, however, was a decline of two from 1989. The next largest block was Japan, with 11 companies, up from 10 in 1989. Europe, as a region, had 22 companies, and the only other country, Saudi Arabia, the remaining one.

The ranking also points out the importance to the industry of the chemical operations of oil companies. There were 10 such chemical units or subsidiaries of oil companies in the ranking, accounting for 23% of the total group sales, $73.9 billion.

The ranking focuses on performance in 1990—not a good year for the global chemical industry. Already facing a downturn in demand and sagging prices, the industry was further battered by the impact of Iraq's invasion of Kuwait, which sent raw material prices into wild gyrations. The result was as anticipated. Operating profits as a percentage of sales declined significantly throughout the industry.

Only the chemical divisions of General Electric in the U.S., and of Anglo-Dutch Unilever Co., for example, showed operating profit margins in the vicinity of 20%. Much more common were operating margins in the low teens—or even less than 10%, a decided fall from 1989 rankings (C&EN, Nov. 5, 1990, page 20).

Now companies are turning their attention to cutting costs, and trying to put through firmer prices, among other things. However, they know there is little they can do while so many of the world's major economies are in recession. And for now, corporate management finds the future to be somewhat cloudy. One thing they agree on, however, is that the end of the recession will be later than predicted by the world's politicians.

In mid-July, for example, following the meeting of the "Group of Seven"—leaders from the U.S., the U.K., France, Germany, Japan, Canada, and Italy—the official declaration proclaimed, "A global recession has been avoided. The uncertainty created by the [Persian] Gulf crisis is behind us. We welcome the increasing signs of economic recovery."

The daily newspapers in Europe—many of whose countries are suffering through tough economic times—were quick to pick up the message, of "Better times are on the way," as one headline put it, with the year ahead bringing a return to economic growth, stable prices, lower interest rates, and more jobs.

However, speaking at the press conference for ICI's half-year results, Sir Denys H. Henderson, chairman of the British chemicals giant, said the economy will remain sluggish through the end of 1992. "Demand is still flat. In the U.S., there are some signs of improvement, with cars and housing, and some pickup in textiles." And in Europe, where many of the chemical industry's markets have been "awful," there is some slight glimmer of movement, he said.

"Put all that together—there will be a slight pickup by the turn of the year—but is that November-December, or January-February? It will be sluggish through 1992, but my crystal ball is cloudy after that," said Henderson.

The British and German economies have provided the two poles of performance in Europe in 1990–91. Germany's output, including that of chemicals, has grown because of demand from the former East German states. The British economy, on the other hand, has been in the grips of recession. When the Association of British Chambers of Commerce, for example, published its second-quarter 1991 quarterly economic survey late in July, the conclusion was a bleak echo of Henderson's predictions: no upturn until mid-1992, at the very earliest.

Other executives in the European industry say that although the slowdown that hit their industry hit Britain hardest, it has nonetheless had an impact elsewhere in Europe. As one executive points out, "Our business was strong in the fourth quarter of

European chemical producers lead as world's largest

Rank 1990	Rank 1989		Chemical net sales ($ millions)	Chemical sales as % of total sales	Chemical operating profits ($ millions)	Chemical operating profit margin[a]
1	1	**BASF (Germany)**	$18,520	64.4%	na	na
2	3	**Hoechst (Germany)**	17,804	64.3	$1171	6.6%
3	2	**ICI (U.K.)**	17,515	76.0	442	2.5
4	5	**Bayer (Germany)**	16,312	63.5	988	6.1
5	4	**Du Pont (U.S.)**	15,571	38.9	1968	12.6
6	6	**Dow Chemical (U.S.)**	14,690	74.3	1925	13.2
7	8	**EniChem (Italy)**	12,571	100.0	620	4.9
8	7	**Shell (U.K., Netherlands)**	12,188	11.5	927	7.6
9	9	**Exxon (U.S.)**	11,153	9.6	737	6.6
10	10	**Rhône-Poulenc (France)**	10,122	70.0	585	5.8
11	16	**Atochem (France)**	9,690	30.0	900	9.3
12	13	**Ciba-Geigy (Switzerland)**	8,150	57.5	441	5.4
13	11	**Union Carbide (U.S.)**	7,621[b]	100.0	1033	13.6
14	15	**Asahi Chemical (Japan)**	6,699[c]	100.0	262[d]	na
15	24	**Hüls (Germany)**	6,300	100.0	306	4.9
16	19	**Akzo (Netherlands)**	5,832	61.2	328	5.6
17	17	**Monsanto (U.S.)**	5,711	63.5	624	10.9
18	25	**DSM (Netherlands)**	5,580	96.3	495	8.9
19	18	**British Petroleum (U.K.)**	5,448	6.7	230	5.9
20	20	**Mitsubishi Kasei (Japan)**	5,321[c]	100.0	128[d]	na
21	14	**Solvay (Belgium)**	5,292	69.3	na	na
22	23	**General Electric (U.S.)**	5,167[b]	8.8	1107	19.7
23	21	**Occidental Petroleum (U.S.)**	5,040	23.2	636	12.6
24	26	**Sumitomo Chemical (Japan)**	4,950	100.0	115[d]	na
25	22	**Norsk Hydro (Norway)**	4,924	50.6	368	7.5
26	31	**Sekisui Chemical (Japan)**	4,144[c]	100.0	180[d]	na
27	27	**Amoco (U.S.)**	4,087	12.9	252	6.2
28	30	**Mobil (U.S.)**	4,084	7.7	397	9.7
29	32	**Toray Industries (Japan)**	4,040[c]	100.0	193[d]	na
30	33	**Showa Denko (Japan)**	3,934	100.0	78[d]	na
31	28	**Takeda Chemical (Japan)**	3,833[c]	100.0	266[d]	na
32	34	**Saudi Basic Industries (Saudi Arabia)**	3,626[e]	100.0	800[d]	na
33	36	**Eastman Kodak (U.S.)**	3,588	19.0	602	16.8
34	40	**W. R. Grace (U.S.)**	3,570	52.9	431	12.1
35	37	**Dainippon Ink & Chemicals (Japan)**	3,489[c]	100.0	57[d]	na
36	39	**Roche (Switzerland)**	3,438	49.4	na	na
37	38	**Chevron (U.S.)**	3,325	8.0	44	1.3
38	—	**Petrofina (Belgium)**	3,259	18.9	367	11.3
39	43	**Unilever (U.K., Netherlands)**	3,089	7.8	398	22.7
40	42	**Mitsui Toatsu Chemicals (Japan)**	3,039[c]	100.0	69[d]	na
41	44	**Mitsubishi Petrochemical (Japan)**	3,000[c]	100.0	179[d]	na
42	12	**Degussa (Germany)**	2,849[f]	33.1	na	na
43	45	**Arco Chemical (U.S.)**	2,830	100.0	469	16.6
44	46	**Rohm & Haas (U.S.)**	2,824	100.0	351	12.4
45	41	**Allied-Signal (U.S.)**	2,786	22.6	287	10.3
46	47	**Air Products (U.S.)**	2,614	90.3	441	16.9
47	49	**Kemira (Finland)**	2,497	83.8	na	na
48	—	**Sandoz (Switzerland)**	2,465	27.7	na	na
49	—	**Courtaulds (U.K.)**	2,288	67.0	238	10.4
50	—	**Teijin (Japan)**	2,279[c]	100.0	138[d]	na

Note: Foreign currencies converted to U.S. dollars using average exchange rate for 1990. **a** Operating profits as a percentage of sales. **b** Contains substantial nonchemical sales. **c** Fiscal year ends March 31. **d** Net profits. **e** Unofficial gross sales. **f** Fiscal year ends Sept. 30. **na** = not available.

1990, and carried on into the first quarter of this year. We didn't see a slowdown until the second quarter. We have probably reached the flat period, with some signs that economies are going to do a bit better. If interest rates come down, there will be a little bit of an improvement, not materially in the second half of this year, not until 1992."

In fact, the executive believes downturns and upturns work roughly on a six- to seven-quarter period, so with the slowdown, from his viewpoint, starting in the first quarter of 1991, the end would not come until the middle of next year.

"There has been improvement in the sense that for petrochemicals, at least," says securities analyst Tony Church, of Wertheim Schroder in London, "the short-term bottom has been reached. Inventories have been cleared out, and a few plastics prices have come off the floor. But I think the turnaround will be next year, not now. Even the traditional optimists in the chemical industry are cautious this time."

The impact of inventories has been important, agrees Peter Vogtländer, chemicals coordinator of Shell International Chemicals Co. in London. "There has been a bit of an artificial demand last year from the [Persian] Gulf crisis: people worried about prices going up, supply security. So they continued to buy. Then the war was over, and the pipeline full—it is now emptying."

As Vogtländer sees it, the industry's customers—particularly major ones such as automobiles and housing—give no reason for optimism, either in the U.S. or in Europe. "There are indications the recession is bottoming out, but no signs of upturns until early 1992 in the U.S. Europe will be running a good six months behind that. Before that works through to the petrochemical level, it may be the end of 1992. It takes time, and I'm not optimistic."

Plant capacity utilization is by no means at 100%, he adds, but it is not so bad as the early 1980s. "We are facing margins not commensurate with present loadings—I would hope the industry would come to its senses and restore margin levels, maybe not to the levels of 1988–89, but better than now." □

Chemical company earnings down again in second quarter
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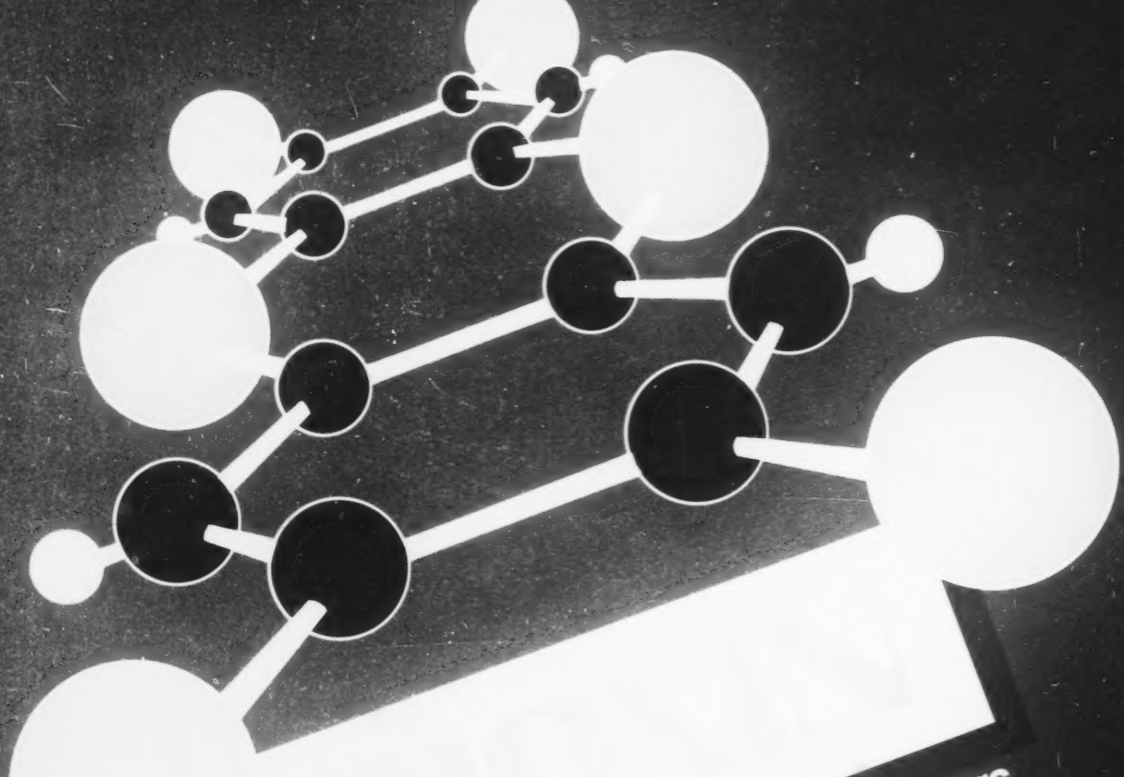

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- **Recent advances in understanding asphalt chemistry promise better, longer lasting roads.** Page 5
- **U.S. chemical industry's ability to compete internationally is projected to continue at least through 2000, but pharmaceutical industry may lose its lead over foreign competitors.** Page 5
- **High-level delegation of Soviet energy officials visits U.S., discusses expanding cooperation in energy-related fields.** Page 6

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Government

U.S. and Soviet Union step up space research cooperation with three new research initiatives and visit by Soviet space officials to NASA facilities. **Page 24**

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Science/Technology

More support for scientists in the Third World, for solving practical problems like fertility regulation and tropical disease treatment, is actively sought by IOCD in U.S. and abroad. **Page 28**

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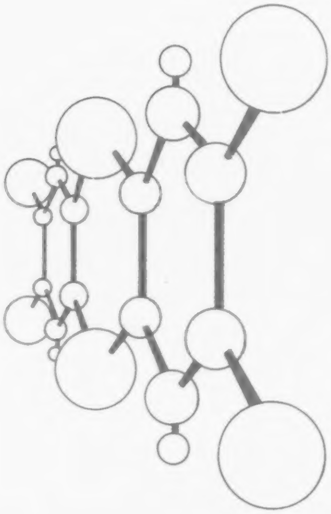

News Focus

Dioxin's toxicity is still an enigma, but new data on Vietnam veterans, among other studies, and insight into how the molecule interacts with DNA may give EPA a firmer basis for regulation. **Page 7**

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Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Charleston explosion

Dèjá vu all over again" was our immediate reaction to the News of the Week article on an explosion and fire in a phosphorus chemicals plant in Charleston, S.C. (C&EN, June 24, page 4).

In 1983, Stan Martin & Associates assisted an investigation of a perplexing explosion in a trimethyl phosphite process facility. Only by postulating an unusual, but quite plausible, (volumetric) thermal explosion resulting from pyrophoricity in trace by-products, were we able to account analytically for the remarkably high explosion overpressures, which were implied by the extensive and severe structural damage. Adding further to the coincidence, the explosion occurred in Charleston.

The similarity may end there, because the 1983 explosion was of high order, while this recent event does not seem to have involved a high-order explosion, based on the appearance of the reactor building in the photograph accompanying the article. Nevertheless, the chemistry may be the same or similar, and the investigating teams may want to review our findings of the earlier accident.

Stanley B. Martin
Proprietor and Principal Investigator
Stan Martin & Associates
Redwood City, Calif.

Video display terminals

Paul Bertan's letter (C&EN, Sept. 3, 1990, page 3) contained remarks that suggested a link between exposure to video display terminals (VDTs) and reproductive problems. Michael S. Plagge (C&EN, Nov. 19, 1990, page 3) and I (C&EN, Nov. 26, 1990, page 54) responded to some of the speculation presented by Bertan. Now Gene Dougherty (C&EN, Jan. 28, page 5) has added additional conjecture that must be challenged. His suggestion that epidemiological investigations "provide overwhelming evidence" of hazards due to electromagnetic fields (EMFs) is without support. The inconsistent findings reported by investigators working on this topic do not allow for an assessment of "overwhelming evidence." Risk ratios between 1.2 and 2.0 (which most of the studies of EMFs show) are extremely difficult to interpret due to the potential confounding of many unrelated factors. For Dougherty to say that it is "silly to continue challenging the epidemiological studies because they are confounded with other variables" is unscientific. To describe the evidence as "overwhelming . . . however confounded" is contradictory.

To suggest that media reporters have acted to have "any discussion of health hazards associated with EMFs or VDTs squelched entirely" is not supported by facts and Dougherty presented none. On the contrary, the president of the National Science Writers Association has said [*Washington Journalism Rev.* **13,** 44 (1991)]: "I can't believe anyone is getting orders from management not to write about this."

Dougherty mentioned (and seemed to dismiss) Plagge's contention that the alleged hazards have been exaggerated by Paul Brodeur. To imply that Plagge's view is at variance with the views of "most responsible citizens, particularly those with scientific training," is not true. In fact many other investigators have criticized Brodeur's reports [for example, *J. of Microwave Power & Electromag. Energy,* **24,** 194 (1989); *Health Phys. Soc. Newsletter,* page 10 (Sept. 1989); *IEEE Spectrum,* **27,** 11 (1990); *IEEE Engineering in Med. & Biol. Mag.,* **9,** 89 (1990); and *Bull. of the Atomic Scientists,* **46,** 46 (1990)].

James R. Jauchem
Research Physiologist
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Ecosystem pollution

I consider Henry Richter's letter (C&EN, May 20, page 2) interesting and important. A couple of other quick calculations, using the data in "Statistical Abstracts of the United States" (1979), demonstrate that we would be buried instantaneously under our solid wastes (296 billion tons per year) if the global population achieved the American standard of living; global internal and coastal water bodies would be burdened with 36 billion gal of pollutants every year—that is, perhaps, all of the inland and coastal water bodies would be irredeemably polluted the first year. These kinds

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Chemical Earnings Average Down Yet Again in Second Quarter

William J. Storck,
C&EN Northeast News Bureau

It's getting to be an old story. For the eighth straight quarter, chemical companies' earnings have declined from the previous year's comparable quarter. And although this year's first-quarter drop showed some moderation of that continuing decline, the second quarter worsened with an 18% decrease from the same period in 1990.

Earnings for oil companies and diversified manufacturers that have chemical operations also declined substantially in the second quarter. Only pharmaceutical companies continued to show an increase, but it seems that they are impervious to the whims of the economy—as long as people get sick and researchers come up with improved and high-value-added products.

For chemical operations, other than pharmaceuticals, the economy continued to take its toll. Poor pricing, higher feedstock costs, lower demand, and a host of other bleak economic factors all played their part.

End-use markets continued weak in the second quarter. The automotive market, a huge outlet for plastics, fibers, and other chemical products, continued to be in the doldrums. Construction, likewise, is showing little sign of vitality overall. Residential construction seems to be picking up somewhat, but commercial construction continues to be depressed as a result of a widely reported nationwide glut of office space.

The upshot is poor demand for chemical products and resulting low

Chemical industry leaders for the second quarter . . .

Sales				Earnings[a]			Profitability		
Rank 1991		$ Millions	Rank 1990		$ Millions	Rank 1990		Earnings as % of sales	Rank 1990
1	Dow Chemical	$4794.0	1	Monsanto	$273.0	2	International Flavors	18.4%	1
2	Monsanto	2473.0	2	Dow Chemical	233.0	1	Loctite	13.4	5
3	Union Carbide	1751.0	3	American Cyanamid	132.0	4	Great Lakes Chemical	11.5	4
4	W. R. Grace	1707.3	4	Union Carbide	64.0	3	Betz Laboratories	11.3	7
5	American Cyanamid	1420.0	5	W. R. Grace	57.6	9	Monsanto	11.0	8
6	Rohm & Haas	752.9	7	Air Products	57.1	8	Nalco Chemical	9.9	6
7	Hercules	734.0	6	Rohm & Haas	52.8	6	IMC Fertilizer	9.7	15
8	Air Products	713.4	8	Ethyl	50.1	7	American Cyanamid	9.3	13
9	Arco Chemical	703.0	9	International Flavors	48.8	10	Crompton & Knowles	9.0	12
10	Ethyl	638.1	12	Great Lakes Chemical	40.0	12	Air Products	8.0	14

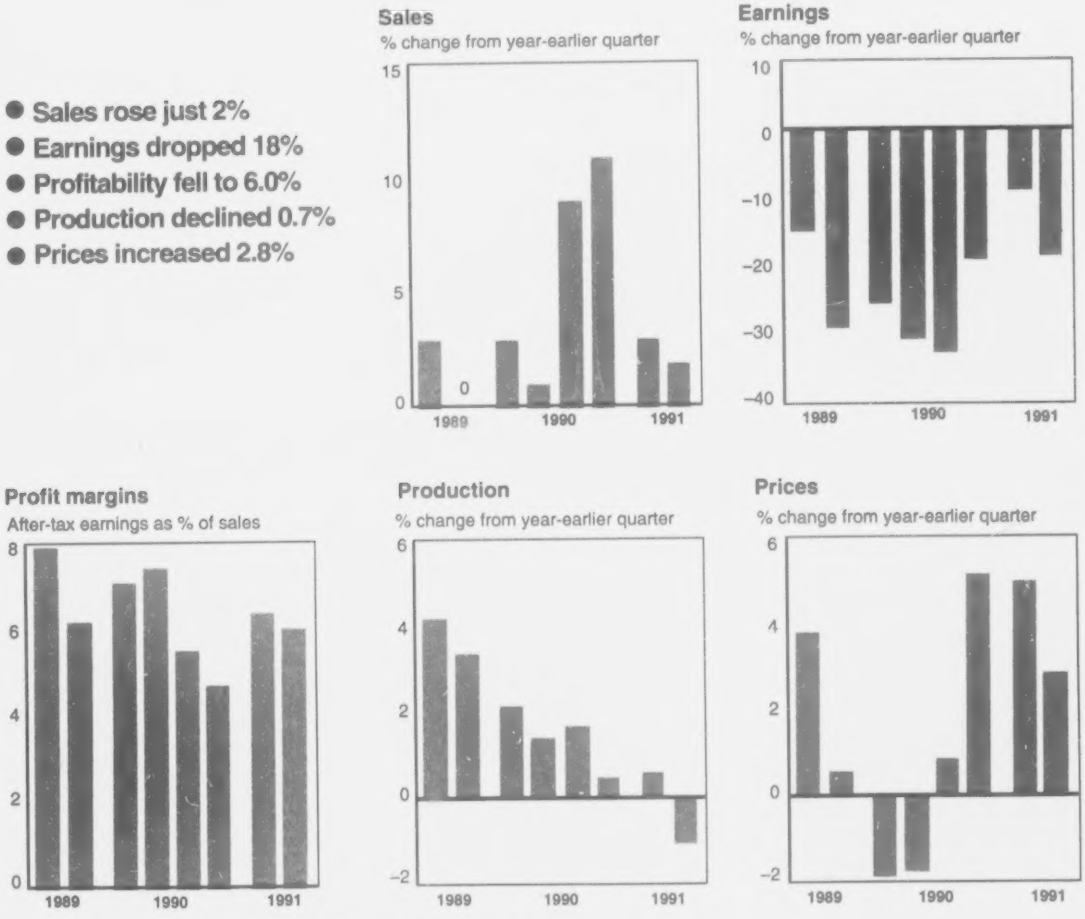
. . . and for the first six months of 1990

Sales				Earnings[a]			Profitability		
Rank 1991		$ Millions	Rank 1990		$ Millions	Rank 1990		Earnings as % of sales	Rank 1990
1	Dow Chemical	$9742.0	1	Dow Chemical	$598.0	1	International Flavors	17.9%	1
2	Monsanto	4696.0	2	Monsanto	439.0	2	Loctite	14.0	4
3	Union Carbide	3608.0	3	American Cyanamid	236.8	4	Great Lakes Chemical	11.8	3
4	W. R. Grace	3350.3	4	Union Carbide	147.0	3	Betz Laboratories	11.2	6
5	American Cyanamid	2732.8	5	Air Products	119.1	6	Nalco Chemical	10.3	5
6	Hercules	1502.0	6	Ethyl	103.0	7	Monsanto	9.3	7
7	Air Products	1468.1	8	International Flavors	95.9	9	American Cyanamid	8.7	10
8	Rohm & Haas	1432.6	7	Rohm & Haas	94.1	5	Lubrizol	8.5	9
9	Arco Chemical	1385.0	9	W. R. Grace	88.4	10	Crompton & Knowles	8.4	13
10	Quantum Chemical	1322.7	11	Arco Chemical	85.0	8	IMC Fertilizer	8.1	17
							Air Products	8.1	15

Note: Based on 30 chemical companies listed on page 18. a After taxes.

Chemical industry 1991 second-quarter results

- Sales rose just 2%
- Earnings dropped 18%
- Profitability fell to 6.0%
- Production declined 0.7%
- Prices increased 2.8%



Note: All sales, earnings, and profit data are based on 30 chemical companies listed on page 18.

capacity utilization, leading to lower prices. Government data show prices for chemicals and allied products rising almost 3% for the quarter. However, this includes drugs and other high-value-added products. On a quarter-to-quarter basis, the average producer price index was off 1.4% in the second quarter of this year for chemicals and allied products when compared with the average for this index during the first three months of 1991.

More indicative of the fortunes of the chemical industry probably is the producer price index for industrial chemicals, which makes up a huge part of industry fortunes. On an annual basis, the average index for the second quarter was up just 1.5% from the same period last year. But on a quarter-to-quarter basis, the second-quarter index was down almost 3% from the first quarter this year.

One company citing the pricing situations was Dow Chemical. Dow said its overall prices were down 1% from last year's second quarter. However, when its consumer specialties segment was excluded, prices for the rest of the company declined 4%. And, when compared with the first quarter of this year, overall prices at the company fell 10%, and were down 13% when consumer specialties were excluded. Dow did, however, say that prices began to stabilize at the end of the second quarter.

These lower prices—combined with a 6% increase in manufacturing costs in the second quarter, when compared with second-quarter 1990—reduced price margins, or the difference between the selling price and the cost to produce the commodity. For Dow, costs of hydrocarbon feedstocks and energy remained flat, but cost increases reflected lower operating rates and higher expenses because of scheduled plant maintenance. The company's operating rate fell to 81% from 89% during the second quarter last year.

Falling capacity use is prevalent

Sales rise 2%, earnings fall 18% for major chemical firms in second quarter

	SECOND-QUARTER 1991						FIRST-HALF 1991			
	Sales	Earnings[a]	Change from 1990		Profit margin[b]		Sales	Earnings[a]	Change from 1990	
	($ millions)		Sales	Earnings	1991	1990	($ millions)		Sales	Earnings
Air Products	$ 713.4	$ 57.1	0%	3%	8.0%	7.8%	$ 1,468.1	$ 119.1	3%	8%
American Cyanamid	1,420.4	131.8	16	22	9.3	8.8	2,732.2	236.6	15	15
Arco Chemical	703.0	33.0	0	−68	4.7	14.5	1,385.0	85.0	0	−18
Betz Laboratories	166.3	18.8	13	15	11.3	11.1	329.7	37.1	13	17
Cabot	347.2	6.4	−12	−59	1.9	4.0	758.0	22.0	−5	47
Crompton & Knowles	119.0	10.7	21	21	9.0	9.0	225.2	18.9	17	20
Dow Chemical	4,794.0	233.0	0	−36	4.9	7.6	9,742.0	598.0	0	−28
Ethyl	638.1	50.1	6	−12	7.9	9.5	1,290.0	103.0	7	−6
First Mississippi	152.2	0.5	4	−31	0.4	0.5	283.4	2.4	8	14
H. B. Fuller	216.3	7.1	6	10	3.3	3.2	418.4	10.8	8	61
Georgia Gulf	214.1	16.6	−2	−50	7.8	15.4	449.6	33.7	−4	−52
B. F. Goodrich	637.0	8.3	1	−76	1.3	5.5	1,214.7	5.4	−1	−89
W. R. Grace	1,707.3	57.6	5	12	3.4	3.1	3,350.3	88.4	7	5
Great Lakes Chemical	346.1	40.0	35	16	11.5	13.5	665.3	78.6	31	14
Hercules	734.0	38.7	−8	22	5.0	3.8	1,502.0	69.2	−4	8
IMC Fertilizer	302.6	29.3	−1	23	9.7	7.7	588.7	47.9	0	18
Imcera	453.2	34.0	13	33	7.5	6.4	862.8	61.2	11	41
International Flavors	266.1	48.8	5	6	18.4	18.1	535.8	95.9	8	10
Loctite	141.0	18.8	1	7	13.4	12.6	279.4	39.1	2	17
Lubrizol	370.1	27.6	4	−17	7.5	9.3	742.4	62.9	4	1
Monsanto	2,473.0	273.0	4	11	11.0	10.4	4,696.0	439.0	1	0
Morton International	465.5	34.2	8	12	7.3	7.1	983.2	74.5	12	7
Nalco Chemical	346.9	34.3	18	4	9.9	11.3	639.1	65.7	12	5
Olin	568.0	21.0	−14	−28	3.7	4.4	1,129.0	42.0	−13	−31
Petrolite	83.4	3.8	16	4	4.5	5.0	161.2	6.6	12	−9
Quantum Chemical	582.5	−40.3	−1	def	def	1.2	1,322.7	−20.8	4	def
Rohm & Haas	752.9	52.8	−2	−25	7.0	9.1	1,432.6	94.1	−2	−24
Chemed	104.6	2.7	8	−40	2.6	4.7	206.9	5.1	8	−36
Union Carbide	1,751.0	64.0	−7	−45	3.7	6.2	3,608.0	147.0	−5	−30
Witco	421.3	16.0	4	−13	3.8	4.6	819.6	32.8	3	−1
TOTAL	**$21,990.1**	**$1328.1**	**2%**	**−18%**	**6.0%**	**7.5%**	**$43,821.2**	**$2701.4**	**2%**	**−12%**

a After-tax earnings from continuing operations, excluding significant nonrecurring and extraordinary items. b After-tax earnings as a percentage of sales. def = deficit.

throughout the industry, brought on by a combination of weak demand and new and upgraded production capacity. The government's measure of capacity use for chemicals and allied products in the second quarter stood at an average 78.1%, off from 78.8% in the first quarter of 1991 and a drop of more than three percentage points from 81.6% in second-quarter 1990.

A continuing high level of chemical product exports—especially plastics—helps keep capacity use from going any lower. However, although the volume of exports is up considerably, industry sources indicate that in many cases, export prices are quite low.

In the second quarter, production, and thus capacity use, was hurt considerably by inventory cutting in downstream markets, according to chemical producers. Downstream users of chemicals had built inventories during the uncertainties in the Persian Gulf region. But as soon as these uncertainties were resolved, inventories were cut to reduce carrying costs, cutting into plant operations and putting further pressure on chemical selling prices.

At Union Carbide, for instance, chairman Robert D. Kennedy said chemical margins continued under pressure as a result of the weak U.S. economy and customer inventory reductions following the end of the war in the Persian Gulf area. Kennedy also mentioned that feedstock costs, although generally declining during the quarter, remain significantly higher than they were a year ago.

The result of all of these pressures cut sharply into earnings for many chemical companies and chemical producers. Of the 30 chemical com-

FIRST-HALF 1990		12-MONTH RUNNING DATA			
Profit margin[b]		Change from 1990		Profit margin[b]	
1991	1990	Sales	Earnings	1991	1990
8.1%	7.7%	10%	15%	8.1%	7.7%
8.7	8.6	5	12	7.0	6.6
6.1	7.5	7	−41	7.4	13.4
11.2	10.9	15	17	11.1	10.9
2.9	1.9	−4	80	3.2	1.7
8.4	8.2	15	38	7.8	6.6
6.1	8.5	9	−37	5.8	10.1
8.0	9.1	5	−4	8.4	9.2
0.8	0.8	8	20	1.0	0.9
2.6	1.7	8	51	3.1	2.2
7.5	15.1	−6	−51	8.3	16.1
0.4	4.2	1	−41	2.9	4.9
2.6	2.7	10	0	3.0	3.3
11.8	13.5	27	14	12.3	13.7
4.6	4.1	0	83	3.9	2.2
8.1	6.9	2	16	8.5	7.5
7.1	5.6	15	65	6.1	4.3
17.9	17.7	11	13	16.4	16.2
14.0	12.2	19	19	12.0	12.0
8.5	8.7	16	33	9.0	7.8
9.3	9.5	4	−16	5.8	7.1
7.6	7.9	16	7	7.3	7.9
10.3	11.0	12	5	10.6	11.3
3.7	4.7	−2	−44	2.7	4.7
4.1	5.0	9	−11	3.9	4.8
def	1.0	10	def	def	2.1
6.6	8.5	3	−1	6.3	6.6
2.5	4.2	11	−4	2.9	3.3
4.1	5.5	−7	−32	4.0	5.5
4.0	4.1	5	−7	3.8	4.3
6.2%	**7.1%**	**6%**	**−17%**	**5.7%**	**7.2%**

panies regularly surveyed by C&EN, 14 had lower earnings in the second quarter than they had in second-quarter 1990. And all of these declines were in the double-digit range, including Quantum Chemical, which reported a loss.

After-tax earnings, excluding significant nonrecurring and extraordinary items for the 30 companies, totaled $1.33 billion, 18% below last year's second quarter. Their combined sales increased just 2% to a total of $22.0 billion. As a result, the average profit margin (earnings as a percentage of sales) declined to 6.0% from 7.5% in last year's second quarter for the same group of companies.

The 18% decline in chemical company earnings scotched any hope given by the first quarter—where a 9% earnings decline had ended a long string of double-digit decreases—that the chemical recession was moderating, if not ending.

Perhaps even just as worrisome is that earnings for the second quarter, which traditionally is stronger than the first, actually came in about 5% below first-quarter results. And sales in the second quarter were essentially flat. Thus, profitability declined to an average 6.0% in the second quarter from 6.4% in the first three months this year.

For the first six months of 1991, earnings for the group of 30 chemical firms were down 12% from the first half of 1990 to $2.70 billion. Sales for the first half were up 2% to about $43.8 billion. Thus, the aggregate profit margin for the companies fell to 6.2% for first-half 1991 from 7.1% during the first six months of last year.

For the remainder of the year, most of the chemical companies see some improvement, but the year is not going to be anything great, they say. Goodrich chairman and chief executive officer John D. Ong says, "Recessionary conditions in most major markets continued to dampen our performance. We are beginning to see improvement in each of our major businesses, but we nevertheless expect economic conditions to remain difficult throughout the balance of the year."

Dow's executive vice president and chief financial officer, Enrique C. Falla, says, "Concerning the business outlook for the remainder of 1991, we expect to see a modest recovery." But, he adds, "The recovery in basic chemicals and plastics will lag due to continuing weak industry fundamentals, while specialties will benefit from the recovery."

At Rohm & Haas, J. Lawrence Wilson, chairman and chief executive officer, says, "The effects of the recession remain with us. Even if the economy were to improve quickly, the Rohm & Haas upturn would lag by at least one quarter. We anticipate full-year results will parallel the performance of the first half, with earnings down approximately 20 to 25%."

Jerry R. Satrum, president and chief executive officer of Georgia Gulf, says: "While the second-quarter results were on a par with the first quarter, we have seen increased weakness in margins for some products in June and into July." Furthermore, he adds, "We

Ground rules for C&EN earnings analysis

C&EN's quarterly report on financial performance of the U.S. chemical industry contains data from the 30 largest U.S. basic chemical companies and from 23 oil and diversified companies, each with more than $200 million in annual chemical sales, plus eight pharmaceutical companies.

To be included in the table of basic chemical producers, a company must have at least 50% of its sales in chemicals. That is why Du Pont, for example, is included in the table of diversified manufacturers.

In referring to chemical sales, C&EN means those chemicals whose molecular composition has been changed in the course of manufacture. Hence, chemical sales include those of traditional categories of basic petrochemicals and inorganics, organic intermediates and inorganic compounds, polymers such as plastics and fibers, and agricultural chemicals and specialty derivatives.

In listing earnings, the survey gives after-tax income for continuing operations before nonrecurring items and extraordinary charges. Foreign currency translations are included.

Drug companies had earnings gain, but oil and diversified firms lost ground

	SECOND-QUARTER 1991						FIRST-HALF 1991					
	Sales	Earnings[a]	Change from 1990		Profit margin[b]		Sales	Earnings[a]	Change from 1990		Profit margin[b]	
	($ millions)		Sales	Earnings	1991	1990	($ millions)		Sales	Earnings	1991	1990
OIL AND GAS COMPANIES												
Amoco	$ 6,744.0	$ 306.0	−9%	−19%	4.5%	5.1%	$ 14,059.0	$ 798.0	−3%	−6%	5.7%	5.8%
Chevron	9,700.0	264.0	9	−55	2.7	6.6	20,500.0	845.0	12	−20	4.1	5.8
Exxon	27,267.0	1125.0	5	2	4.1	4.2	57,952.0	3816.0	10	9	6.6	6.6
Fina	823.6	4.2	−1	−92	0.5	6.5	1,639.5	12.5	−5	−84	0.8	4.6
Kerr-McGee	784.2	10.3	−5	−66	1.3	3.7	1,569.8	40.0	−2	−30	2.5	3.5
Mobil	14,449.0	401.0	5	−6	2.8	3.1	31,029.0	1111.0	8	30	3.6	3.0
Occidental Petroleum	5,056.0	50.0	−1	79	1.0	0.5	10,359.0	133.0	1	−4	1.3	1.3
Phillips Petroleum	3,150.0	33.0	10	−69	1.0	3.7	6,435.0	219.0	8	74	3.4	2.1
Shell Oil	5,345.0	22.0	3	−86	0.4	3.1	11,013.9	147.0	1	−60	1.3	3.3
Sun Co.	3,090.0	43.0	7	−63	1.4	4.0	6,140.0	84.0	2	−55	1.4	3.1
Texaco	9,031.0	269.0	4	−24	3.0	4.0	19,211.0	684.0	7	0	3.6	3.8
Unocal	2,725.0	5.0	0	−85	0.2	1.2	5,442.0	80.0	2	−27	1.5	2.1
TOTAL	**$88,164.8**	**$2532.5**	**3%**	**−25%**	**2.9%**	**4.0%**	**$185,349.3**	**$7969.5**	**6%**	**0%**	**4.3%**	**4.6%**
DIVERSIFIED MANUFACTURERS												
Allied-Signal	$ 3,047.0	$ 89.0	−4%	−26%	2.9%	3.8%	$ 5,950.0	$ 152.0	−5%	−39%	2.6%	4.0%
Du Pont	9,825.0	549.0	2	−21	5.6	7.2	19,504.0	1139.0	2	−13	5.8	6.9
Eastman Kodak	4,989.0	357.0	2	−7	7.2	7.9	9,411.0	535.0	5	−8	5.7	6.5
Engelhard	649.2	22.9	−14	26	3.5	2.4	1,277.9	44.0	−9	34	3.4	2.3
FMC	1,046.6	62.5	6	14	6.0	5.6	1,924.0	101.2	7	9	5.3	5.2
Ferro Corp.	270.1	9.9	−4	39	3.7	2.5	533.0	12.8	−5	−2	2.4	2.3
3M	3,349.0	299.0	4	−13	8.9	10.6	6,738.0	599.0	5	−12	8.9	10.6
NL Industries	217.2	18.5	−6	−55	8.5	17.7	442.3	27.7	−3	−58	6.3	14.3
PPG Industries	1,477.9	79.1	−6	−44	5.4	9.0	2,854.6	101.0	−6	−62	3.5	8.7
Tenneco	3,506.0	−14.0	−4	def	def	5.7	6,837.0	−13.0	−6	def	def	4.2
Vulcan Materials	266.4	25.9	−10	−35	9.7	13.4	463.4	23.7	−12	−59	5.1	11.1
TOTAL	**$28,643.3**	**$1498.8**	**0%**	**−27%**	**5.2%**	**7.1%**	**$ 55,935.2**	**$2722.3**	**0%**	**−25%**	**4.9%**	**6.6%**
PHARMACEUTICAL COMPANIES												
Abbott Laboratories	$ 1,683.0	$ 268.3	12%	12%	15.9%	16.0%	$ 3,336.6	$ 522.4	13%	12%	15.7%	15.8%
American Home Products	1,619.5	265.2	14	32	16.4	14.1	3,383.8	617.7	−1	20	18.3	15.1
Baxter International	2,197.0	141.0	10	28	6.4	5.5	4,319.0	251.0	11	def	5.8	def
Bristol-Myers Squibb	2,730.4	489.5	10	17	17.9	16.8	5,465.1	982.1	11	19	18.0	16.7
Pfizer	1,531.1	179.1	9	18	11.0	10.1	3,326.8	446.5	12	11	13.4	13.5
Schering-Plough	912.9	167.4	6	16	18.3	16.7	1,862.2	340.6	8	16	18.3	17.0
Upjohn	859.4	127.5	14	12	14.8	15.2	1,658.7	260.8	12	13	15.7	15.6
Warner Lambert	1,238.2	154.6	7	15	12.5	11.6	2,455.4	294.1	9	15	12.0	11.3
TOTAL	**$12,871.5**	**$1792.6**	**10%**	**19%**	**13.9%**	**12.9%**	**$ 25,807.7**	**$3715.2**	**9%**	**37%**	**14.4%**	**11.5%**

a After-tax earnings from continuing operations, excluding significant extraordinary and nonrecurring items. b After-tax earnings as a percentage of sales. def = deficit.

have not seen many encouraging signs of an immediate economic recovery. This could result in some further margin losses before a strengthening of the economy becomes readily apparent."

Cabot Corp. chairman Samuel W. Bodman hedges somewhat by saying, "The recession impaired volumes and margins in our manufacturing operations, while record low gas prices severely depressed the summer market for liquefied natural gas. There are some signs that conditions may be improving, but we are cautious about the immediate future."

While the 18% drop in earnings for the chemical companies was bad, these firms should be happy that they are not oil companies or diversified manufacturers. Earnings at 12 oil companies surveyed by C&EN dropped 25% to $2.53 billion on a 3% sales increase to $88.2 billion. This caused the average profit margin for the group to fall to 2.9% in the second quarter from 4.0% in the same period a year earlier. For the six months, earnings at the companies were flat at $7.97 billion on a 6% sales increase to $185 billion. Profit margins for the group dropped to 4.3% from 4.6% in first-half 1990.

For 11 diversified manufacturers, second-quarter earnings fell 27% to a total of $1.5 billion on flat sales of $28.6 billion, causing the group's profit margin to fall to 5.2% from 7.1% in last year's second quarter. For the six months, earnings were off 25% to $2.72 billion on $55.9 billion in sales, essentially the same figure as in first-half 1990. This depressed profit margins to an average of 4.9% through June of this year from 6.6% in the same period last year.

In stark contrast stand the pharmaceutical manufacturers. For these eight companies, earnings for the quarter rose an average 19% to $1.79 billion on a 10% sales increase to $12.9 billion. Profit margin for the group was 13.9%, up from 12.9% in second-quarter 1990. For the first half, earnings for these companies were up 37% to $3.72 billion on a 9% sales increase to $25.8 billion. And the profit margin for the group rose to 14.4% from 11.5% a year earlier. However, the increases in first-half earnings and profitability for pharmaceutical producers are tainted somewhat by a nonrecurring charge recorded in the first quarter of 1990 by Baxter International, which threw the company into a deficit. Baxter did not state the charge in after-tax terms, so it is impossible to remove its effect from the company's results. ☐

Chemical earnings drop at oil companies

While earnings at major chemical companies were falling 19% in the second quarter, earnings from chemical operations at oil companies were dropping almost twice that much. Because oil companies report net income from chemical operations, this measure provides a good look at what is happening in the petrochemical industry.

For seven oil companies with large chemical businesses—Chevron, Exxon, Mobil, Occidental Petroleum, Phillips, Shell, and Unocal—earnings from chemical operations dropped an average of 37% to a combined $462 million in the quarter.

Of the seven firms, only Unocal had an increase in chemical earnings, but what an increase it was, especially compared with the other companies. Unocal posted a 50% increase to $24 million in the second quarter. The company says very little about these results, except that "higher second-quarter earnings reflected increased margins for industrial chemical products."

The best performance among the other six companies came at Occidental, where chemical earnings were down 26% from the second quarter to $127 million. The company says the lower earnings were the result of lower margins in petrochemicals, electrochemicals, and polymers and plastics. This was primarily caused by lower sales prices and higher feedstock and raw material costs. In spite of the decline in earnings at the company, Occidental still rang up a more than respectable chemical profit margin of 10.7% for the quarter.

Exxon, the oil company with the largest chemical sales, also blamed higher feedstock prices, plus weak economic conditions and industry overcapacity for lower margins in chemicals, both in the U.S. and overseas. Exxon's chemical earnings fell 36% to $111 million in the second quarter.

The story was pretty much the same at the other oil companies, all citing lower margins in chemicals from higher feedstock costs and lower selling prices. And all are blaming—and waiting for the end of—the recession in the chemical industry.

	CHEMICAL EARNINGS		
	Second quarter		
$ Millions	1991	1990	% change
Chevron	$ 36	$ 65	–45%
Exxon	111	174	–36
Mobil	61	94	–35
Occidental Petroleum	127	172	–26
Phillips	45	120	–63
Shell	58	90	–36
Unocal	24	16	50
TOTAL	$462	$731	–37%

Petrochemical prices slated to rise

For petrochemical producers, these are anything but happy times. Demand is down because of recession or sluggish conditions in many of the industry's primary end-use markets, and because many customers are still working off high inventories of materials. Following major disruptions caused by the invasion of Kuwait and the subsequent war in the Persian Gulf, prices of feedstocks are high. With prices of their materials even lower than the months leading up to the Gulf War, however, profit margins are being squeezed severely.

Producers are getting restive. Despite the continuing unfavorable market conditions, it seems clear that producers will be going all out this autumn to put through price increases. Whether those increases stick remains to be seen. But a determined effort will clearly be there.

First salvos on the front to raise prices came late last month from Himont and BP Chemicals. Himont, part of the Montecatini chemicals group in Italy, and the world's largest producer of polypropylene, says it is determined to "follow through on the price initiative in Europe," embarked upon in May, to raise polypropylene prices.

The company's goal is to achieve a minimum target price of about 36 cents per lb for polypropylene, effective Sept. 1. The July price ranged from 29 to 31 cents per lb. The new target price would pertain to raffia-grade homopolymer resins; general purpose injection grades would be set at 38.8 cents per lb and medium-impact copolymer, at 45 cents per lb. With raw material prices expected to remain stable, prices could be maintained through the remainder of 1991, the company says.

Meanwhile, BP Chemicals' marketers in London have pulled together a comprehensive picture of the grim business in polyethylene.

BP Chemicals links the fall in profitability directly to the crisis in the Middle East. Up to that time, the industry was stable; demand, albeit slowing down from recessionary pressures, matched supply. Then came Iraq's invasion of Kuwait, and

AUGUST 19,

CHEMICAL & ENGINEERING NEWS

cts & Figures for hemical R&D

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CENEAR 69 (33) 1–92
ISSN 0009-2347

CHEMICAL & ENGINEERING NEWS

AUGUST 19, 1991

News of the Week

- **A plan to destroy Iraqi chemical weapons has been submitted to the United Nations and, if approved, could be undertaken fairly soon.** **Page 6**
- **Pact between an Arizona electric power plant and an environmental group would cut sulfur dioxide emissions 90%, reducing haze that often obscures the Grand Canyon.** **Page 7**
- **On just concluded mission of space shuttle *Atlantis*, biochemist astronaut performs chemical-related experiments under microgravity conditions.** **Page 7**
- **Eastman Kodak is restructuring again and plans to reduce its imaging and information systems work force by 3000, mostly by early retirement.** **Page 7**
- **Some chemical and other nonelectric uses of concentrated solar energy show promise, says a study by a National Research Council panel.** **Page 8**
- **Frederick E. Bailey, director on the ACS Board from Region II, has died at the age of 63.** **Page 8**

Cover: Photo courtesy of Bristol-Myers Squibb

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Business

Ethylene glycol production in the U.S. will falter this year, but rising demand—possibly amounting to about 5.3 billion lb—will be met by drawing down inventories of this key ingredient for antifreeze. **Page 11**

Government

Chemical weapons treaty with teeth is urged by Democratic Rep. H. Martin Lancaster, a leading Congressional voice pushing for a global ban on such arms. **Page 15**

Education

Pacific Rim nations assess their future technical education needs in light of current economic realities as they strive to better prepare their countries for competition in the international marketplace. **Page 21**

ACS News

ACS education programs ranging from elementary school to college level get major boost from grants from such funding sources as NSF and the society's Campaign for Chemistry. **Page 74**

Chemical R&D

C&EN's annual compilation of data on chemical R&D shows modest growth for 1991, with overall spending in the U.S. likely to top $151 billion, a 4% increase over last year. **Page 32**

Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
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Subscription Rates 1991: Printed editions: nonmembers U.S. 1 yr. $95, 2 yr. $171; outside U.S. 1 yr. $131, 2 yr. $243. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $12. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Keeping the word chemical

Ronald J. Gillespie made a particularly interesting point in his letter (C&EN, Dec. 10, 1990, page 4). The word chemical is not defined in chemistry texts! Gillespie notes that "chemists often use the word in the sense of a substance produced by the chemical industry." The "World Chemical Outlook" feature in the same issue certainly reinforces that point.

Examples cited in the letter suggest that it is common for nonchemists, too, to recognize the history of a sample of matter in selecting what term to apply. Usage seems consistent with the definition of chemical as a sample of substance produced, extracted, or marketed in a consistent form. Dioxygen industrially separated from the atmosphere is thus a chemical, but not what we breathe. Ozone generated from water purification is a chemical, but not that formed in the stratosphere. Sucrose producers become chemical firms, but the sugar contained in a raisin is just a constituent, not a chemical.

Gillespie is certainly not the only chemist objecting that "chemical" involves a sample's origin as well as its changing composition. Yet there would be great difficulty in changing the common concept. For example, it would be interesting to learn of marketing research results related to the 1989 National Chemistry Week campaign to have students label everything with "This is a product of chemistry" tags. The idea may be acceptable to chemists, but I suggest the paradigm shift for the public was too challenging to be accomplished except with an unusual degree of local backup.

It is folly to expect that "chemical" might go unused because chemists abandon it due to a current, pejorative sense to the word. Some public perception of danger is valid; in the concentrated form we use, many chemicals are poisonous. Rather than trying to sidestep this fact by going to "substance," let us use "chemical" with pride. Think of an example from your own experience to get you started. General acceptance of the definition above may benefit chemistry by clarifying the equivalence of some chemicals and valued materials referred to by application names: detergent, pigment, medication. (See David Shobe's letter, C&EN, Dec. 17, 1990, page 2.)

It is true that dictionary definitions of chemical are poorly differentiated from substance. I suggest that chemists work to tighten up the definition, rather than do away with the word.

James A. Carroll
Department of Chemistry
University of Nebraska
Omaha

Chemical Bank and Manufacturers Hanover have just announced their pending merger, and the name they have chosen to keep for the merged bank is Chemical Bank. Perhaps this will put a little spirit into the society's members quivering over the word "chemical."

Michael Macomber
Kensington, Calif.

Radon and lung cancer

My repeated attempts to question the Environmental Protection Agency about the low level of 4 picocuries (pCi) per L as a hazard level for radon gas in homes has met with little success. It appears that radon is guilty until proven innocent of causing lung cancer.

EPA claims that "the harmful effects of radon do not appear until many years after exposure." This type of statement has been used to cause public alarm for many chemicals. Radon is not a new man-made chemical. The effects of radon have happened in the past, are happening now, and will happen in the future. Therefore, we can evaluate the deaths from lung cancer today and not have to wait.

Earl Ubell reported in November 1990 that "of the 140,000 deaths from lung

Corrections

- July 1, page 43: 1-Trimethylsilylpropyne is available in the U.S. from Aldrich Chemical as well as from Hüls America.
- July 29, page 20: *Materials & Processing Report* is published by Elsevier Science Publishing Co., New York City. Renée G. Ford is its editor.
- Aug. 5, page 4: The photograph of the tankcar derailment at Dunsmuir, Calif., should have been credited to Jay Mather, *Sacramento Bee/* SYGMA.

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Ethylene Glycol Supplies Will Be Sufficient To Meet Rising Demand

Producers of this glycol, the key ingredient in antifreeze, plan to offset small decline in production this year by drawdown of inventories

Bruce F. Greek, C&EN Houston

As winter, the season of highest consumer demand for antifreeze, draws ever closer, producers of ethylene glycol, the key ingredient in antifreeze, believe that supplies will be sufficient to meet U.S. demand and export needs. What's more, they think there will be enough for glycol's other uses, too, including polyester fiber, film, bottle and engineering resins, and several small-volume specialty uses.

Ethylene glycol production in the U.S. this year will likely be down about 300 million lb from last year, to about 4.6 billion lb, the result of an explosion and fire at an ethylene oxide unit of Union Carbide's Seadrift plant in Port Lavaca, Tex. (C&EN, March 18, page 6). About 500 million lb of ethylene glycol will be imported, mostly from Canada, for a supply total of about 5.1 billion lb.

Consumption is expected to rise this year as the recession continues to ease, possibly increasing to about 5.3 billion lb. The excess glycol will come from a drawdown of inventories, a reversal of the situation last year when production and imports at 5.5 billion lb exceeded U.S. demand and exports by about 300 million lb.

Producers other than Carbide are expanding ethylene glycol output, partially to offset the lost production. For example, PD Glycol (a joint venture of Du Pont and Occidental Chemical) added 100 million lb of capacity at its Beaumont, Tex., plant at the start of the third quarter.

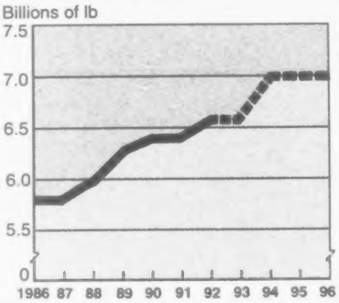
Total U.S. capacity to make ethylene glycol at the beginning of this year was about 6.4 billion lb. About 5.7 billion lb of the capacity makes monoethylene glycol, the most commercially significant compound. Di- and triethylene glycols are made in much smaller quantities along with monoethylene glycol and go into some of the same applications. (Unless otherwise indicated, ethylene glycol in this article means the mono form.)

Despite lower U.S. production, world output of ethylene glycol is expected to reach about 19 billion lb this year. This will mark an increase of more than 2% from less than 18.5 billion lb in 1990, says M. Peter Bellis, vice president of Chemical Marketing Associates Inc. (CMAI) in Houston. World consumption will grow at an average annual rate of 4.4% from 1991 to 1996, according to CMAI's recently released study, 1991 World Ethylene Oxide/Ethylene Glycol Analysis, the preparation of which Bellis directed.

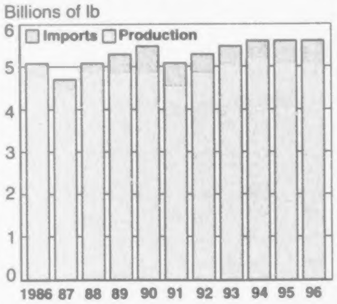
In the U.S. and Western Europe, polyester resins for bottles, film, and engineering uses will spur ethylene glycol growth, Bellis says. Polyester fiber production will be the driving force behind consumption growth in the Far East.

Despite a sizable capacity expansion now coming on stream in South Korea, and despite more capacity currently under construction or planned for in that country and in other Asian locations, imports will be needed to meet the demand in the Far East. Part of this demand for imports will be supplied by new capacity built in Canada and Saudi Arabia. U.S. exports to the Far East will remain sizable, although Bellis

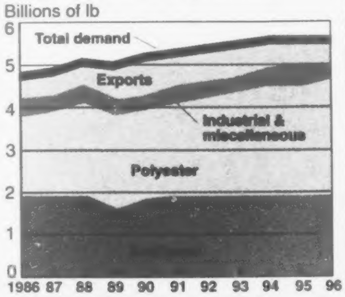
U.S. ethylene glycol capacity grows . . .



. . . as imports' share of supply shrinks . . .



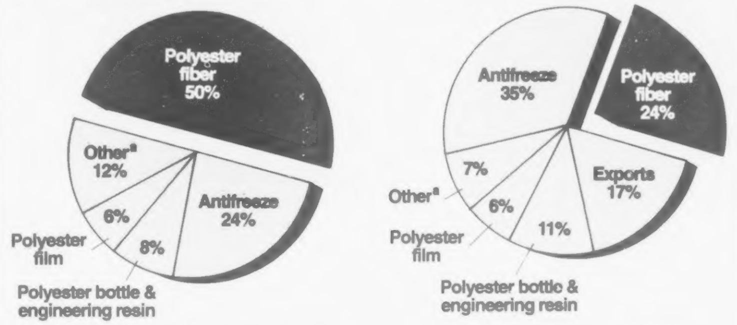
. . . and lower exports offset demand growth



Note: Data for years 1991–96 are forecasts.
Source: Chemical Marketing Associates

Fibers dominate global use of ethylene glycol . . .

. . . but make up less than one quarter of U.S.'s use



1990 global consumption = 13.7 billion lb

1990 U.S. consumption = 5.21 billion lb

Note: Data are for monoethylene glycol. **a** Includes chemical reactants, coatings, solvents, and comonomers in unsaturated polyester and acrylic resins. **Source:** Chemical Marketing Associates

forecasts that they will decline slowly over the next five years. Western Europe will continue to import glycol because a growing share of ethylene oxide production in that region will be used to make more profitable derivatives.

Global consumption patterns for ethylene glycol differ significantly from those in the U.S. Polyester fiber accounts for half of world use, and antifreeze makes up less than a quarter. In contrast, in the U.S. more than one third goes into antifreeze and less than one fourth goes for making polyester fiber. Exports of glycol, particularly to the Far East, were more than 870 million lb, more than a sixth of U.S. consumption in 1990.

Last year, a large share of growth in U.S. demand for ethylene glycol (up 3.9% over 1989) resulted from a rebound in the demand for antifreeze. Sales of ethylene glycol-based antifreeze in the U.S. amounted to more than 192 million gal, according to a survey conducted by the Chemical Specialties Manufacturers Association. Sales last year were up more than 19% over the 161 million gal sold in 1989.

Antifreeze consumption this year will amount to about the same as in 1990, according to most industry sources. For example, lower automobile production reduces the original fill use of antifreeze, but that situation is offset by increased demand for replacement material, because cars are kept on the road longer, points out Ronald L. Gist, a senior consultant at Pace Co. in Houston. Earlier this month, there was almost no concern about antifreeze supplies for the coming winter, Gist says, despite indications that inventories of ethylene glycol will be reduced this year.

Growth in use of ethylene glycol in antifreeze will be low worldwide between 1991 and 1996, at 0.9% annually, according to the CMAI analysis. U.S. growth is forecast at even less—0.6% annually—which suggests that the historical pattern of large swings in annual antifreeze sales will continue.

Polyester fiber uses of ethylene glycol in the world, now slightly less than 50% of the total, will grow 5.1% annually through 1996 or faster than total consumption at 4.4% annually. By 1996, fiber uses will be 52% of total world consumption, or about 9.3 billion lb, according to the CMAI study.

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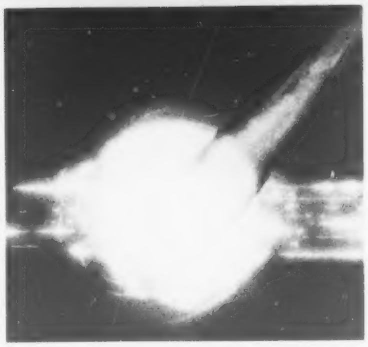
U.S. demand for polyester fiber will grow an average 1.8% a year through 1996 and will account for nearly 25% of glycol consumption. The slow growth stems from modest recovery in fiber demand following a downturn in the 1990–91 recession.

The brightest outlook for polyester use of ethylene glycol both globally and in the U.S. is for bottle and engineering resins. Bellis estimates worldwide growth at 9.7% annually through 1996, just ahead of U.S. growth of 8.5% annually. By 1996, U.S. bottle and engineering resins will require 16% of total glycol consumption, up from about 11% in 1990. Global use for these resins will take 11% of total consumption, up from less than 9% in 1990.

Polyester use for film also is expected to grow faster than fiber use, both worldwide and in the U.S., but only about 60% as fast as in bottle and engineering resins. Because of stringent performance requirements of the end uses of polyester films (such as in photographic and magnetic media), the resins are purified more than those used in making fibers, rendering ethylene glycol quality requirements even higher.

Quality requirements for the ethylene glycol that goes into polyester resins make that glycol more expensive to manufacture than antifreeze or industrial grades. There typically is a spread of 1 to 2 cents per lb between fiber and antifreeze grade prices. Currently, contract ethylene glycol prices range from 21 to 23 cents per lb for fiber grade and 20 to 22 cents per lb for antifreeze grade. Spot prices on the Gulf Coast are 1 to 2 cents lower than contract prices. By the end of the third quarter, prices are expected to decline again 0.5 to 1 cent per lb.

Prices of ethylene glycol are falling, as are the prices of all major ethylene derivatives, because ethylene prices continue to decline. However, partially because of the expected shrinkage of ethylene glycol inventories, relative prices have declined less than ethylene prices. Next year when all existing capacity is operable and expansions and process improvements are complete, prices may decline more rapidly as inventory is rebuilt. □



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Pacific Rim Nations Assess Future Technical Education Needs

Conference on science and engineering education systems of Pacific Rim countries focuses on readjustments needed to succeed globally

Joseph Haggin, C&EN Chicago

Most of the Pacific Rim, by some accounts, is living on the sharp edge of economic disaster. To stave off this threat, some countries are putting increased emphasis on planning for their technological futures. They are starting with the universities, where the engineers and other technical professionals of the future will be trained.

Likely technological emphases for the rest of the 1990s are accelerated energy production, the emergence of new materials, further "revolutions" in telecommunications, better housing, and environmental improvement. All of these technological efforts will need to evolve in the face of increasing population pressures, especially in the developing nations, and the need to improve living standards around the world.

One of the keys to success in these technological areas will be more and better engineering education. Globalization is no longer limited to industry, politics, and economics. Engineering education also is becoming distinctly globalized, and this poses many unique challenges for educators and the profession alike.

To assess the problems of engineering education common to the Pacific Rim countries, the University of Illinois, Chicago, convened a conference on the subject last month. Called "Engineering: A Global Enterprise," the conference was jointly chaired by Paul M. Chung, dean of the university's college of engineering, and James P. Hartnett, professor in the college's mechanical engineering department. Representatives from such Pacific Rim nations as China, Taiwan, South Korea, and Japan attended, along with U.S. representatives. The Japanese, though, kept a low profile at the meeting.

Since World War II, the flow of technology transfer and technical education has been from western nations to eastern ones. This situation, however, is now changing considerably.

Strong growth at Chinese universities in past 40 years

	1990	1980	1978	1949
Universities	1,075	675	598	205
Engineering schools	285	203	184	28
Undergraduates	2,065,900	1,143,700	856,300	116,500
Engineering students	745,600	383,500	287,600	30,300
Graduate students	84,158	21,604	—	—
Engineering graduate students	38,470	7,206	—	—
Teaching and administrative staff	1,004,700	631,900	518,400	46,000
Academic faculty	394,500	246,800	206,200	16,100

Source: Office of the President, Tianjin University, China

Korean science, engineering enrollments have blossomed

		Number of departments	Number of degrees awarded			Faculty	Student to faculty ratio
			B.S.	M.S.	Ph.D.		
1965	Science	108	9,331	281	10	751	13.2:1
	Engineering	130	17,332	312	3	540	33.2:1
	TOTAL	**238**	**26,663**	**593**	**13**	**1291**	**21.6:1**
1970	Science	126	12,972	319	35	870	15.7:1
	Engineering	232	22,817	509	19	932	15.6:1
	TOTAL	**358**	**35,789**	**828**	**54**	**1802**	**20.8:1**
1975	Science	141	14,472	713	154	1128	14.4:1
	Engineering	268	43,005	1,285	131	1300	35.3:1
	TOTAL	**409**	**57,477**	**1,998**	**285**	**2428**	**25.6:1**
1980	Science	290	31,338	2,145	463	1739	21.0:1
	Engineering	478	99,568	5,154	630	2340	47.5:1
	TOTAL	**768**	**130,906**	**7,299**	**1093**	**4079**	**36.0:1**
1985	Science	409	83,743	3,805	1424	3194	29.5:1
	Engineering	476	189,069	8,822	1712	3600	58.4:1
	TOTAL	**885**	**272,812**	**12,627**	**3136**	**6794**	**44.8:1**
1990	Science	419	94,419	3,897	1487	4057	21.6:1
	Engineering	720	239,436	11,861	2898	5038	50.4:1
	TOTAL	**1139**	**333,855**	**15,758**	**4385**	**9095**	**38.9:1**

Source: Office of the President, Seoul National University, South Korea

Telecommunications: vital to global competitiveness

Training a population to be competitive in the global marketplace more and more means dealing with the "revolution" in telecommunications systems. It also means preparing to learn—and use—telecommunications systems now on the drawing board. Staying current in order to best prepare students for the demands of the technological world places a heavy, and costly, demand on technical education systems in developed countries. And it is likely to place an extraordinary demand on such systems in developing countries.

But, according to Bernard F. Sergesketter, vice president of AT&T Bell Laboratories who spoke at the recent University of Illinois, Chicago, conference, it is vital that education systems meet this demand. He believes the future health of global industry and commerce hinges on it.

The current impact of telecommunications technology may be gauged by considering some data on "fax traffic" flowing between the U.S. and Japan. About 26% of all message traffic to Japan is now fax messages. The fax traffic from Japan to the U.S. is 60% of all message traffic.

One expectation for future telecommunications developments is in the area of satellite publishing. The use of this technology is a necessity, says Sergesketter. Even more important may be the realization of the potential for fiber optics and improved computational power.

In addition to the transmission of messages by fiber optics, the optical computer will probably make available the power necessary to handle the coming revolution in software—speech processing. One very important application is human-to-human communication through natural language barriers. The software necessary for such translation is under development. It not only will permit the direct translation of messages but also will offer the user the opportunity to search any electronic database in the world. According to Sergesketter, successfully using these and other telecommunications technologies is likely to be vital to nations that will be competing in the global marketplace of the future—and to students these countries are educating to help them stay competitive.

Starting from scratch, many of the eastern countries have built formidable systems for technical education. But some constraints, derived from national philosophies and cultural beliefs, remain. In observations made after the conference, Chung noted the U.S. also has some built-in constraints that must be removed.

In the U.S., engineering education emphasizes mathematics, science, and research. As global interdependency grows, he says, engineers must be more artful in areas such as economics, international management, communications, and languages. Chung also believes engineering education should impart social, cultural, and language skills to future engineers. He believes most engineers are ill-prepared to function in an international environment.

According to Chung, U.S. engineering schools overemphasize basic science and engineering at the expense of practical design and consumer-oriented applications. For example, he observes that the U.S. education system does not teach what is in Japan a honed skill—how to use technology to produce consumer products. "Engineers must be taught to commercialize their own technology," he says. Similarly, Americans are so confident of their wealth, power, and technical dominance that engineering students are not encouraged to consider seriously the successes of other nations. He adds that 30 years ago the Pacific Rim nations began to study U.S. technology. They took what best fitted their needs and cultures, and what supported their national goals. Americans still have difficulty in extracting what works for them from the Japanese, Chinese, and Koreans.

The educational problems certainly are not restricted to the U.S.; most of the Pacific Rim countries have an equitable share. Foreign students in the U.S. may learn technology but not U.S. culture or the way Americans do business. Like their U.S. counterparts, foreign students must be equipped with the cultural and communications skills to function internationally. With a few individual exceptions, all the Pacific Rim countries represented at the conference are struggling with these problems.

A side debate going on during the conference centered on the serious consideration now being given to an international standard for engineering education. People also discussed, in private, the possibility of an international accreditation body for the Pacific region. Such topics invariably excite passions—usually negative ones—among educators.

Chung notes that international commerce is necessary for survival and that engineering is an integral part of the industrial and commercial effort. The faculties in many engineering schools are already becoming international in character. At the college of engineering of the University of Illinois, Chicago, 22 of the 115 faculty members are of Asiatic origin, 14 being Chinese, Korean, or Japanese, and eight Indonesian or Indian. In addition, many cooperative programs now are operating between universities. The University of Illinois, Chicago, now has working relationships with a number of Asian universities, including Korea University in Seoul, Tsinghua University in Beijing, and the University of Tokyo. Arrangements with universities in other parts of the world also are common.

When the educational problems are considered from another perspective, matters change considerably. Wan-Kyoo Chu, president of Seoul National University in South Korea, leaves no doubt that that university was very closely wedded to the economic prosperity of South Korea. He is worried about the developing countries running into "ever higher walls of protectionism" from the developed nations. The collapse of communism in Eastern Europe has caused a rekindling of interest in European development among capitalists. But that interest may dwindle as the problems of converting those economies from communism come into sharper focus.

Chu believes the "rising dragons"

of the Pacific have three main problems: barriers to technology transfer, the Uruguay round of the General Agreement on Tariffs & Trade, and the backward nature of their industries.

Since World War II and the Korean War, South Korea has managed to eliminate its foreign debt and boost its per-capita gross national product from $50 to $5000. At the same time, annual trade volume has risen from $10 million to $130 billion. The main reason for this nation's lack of optimism over its immediate future is its lack of scientific and technical education, which has reached the crisis stage, Chu says.

Before World War II, the colonial powers placed severe limitations on native educational institutions and did little to improve the training of administrators and other professional people. Japanese colonials established Keijo Imperial University in Seoul, but it was almost entirely populated by Japanese nationals, according to Chu. Only three Koreans received a B.S. degree in physics between 1910 and 1945. Only 30 Koreans obtained engineering degrees during the entire colonial period.

A major education-associated problem for South Korea has been finding qualified educators. Following World War II, only about a dozen such people were available to fill all the jobs in the natural sciences and engineering. Most of the potentially qualified people were employed in government or industry. As a result, most of South Korea's college graduates had to go to the U.S. to study in these fields—and many didn't return home.

Upturns in the South Korean economy in the 1960s caused college enrollments to increase sharply. By 1990, South Korea had a million undergraduates, 87,000 graduate students, and 42,000 professors. However, faculty growth has not been able to catch up with demand: The faculty-to-student ratio has dropped to 1:39 for all collegiate work and to 1:50 for engineering training. And indicators point to a worsening situation.

The first major technology institutes in South Korea were founded in 1962. A few years later the government established the Ministry of Science & Technology and, in 1970, the Korean Advanced Institute of Science & Technology. The economic setback, caused by the oil crisis of 1972–76, did not prevent educational progress. Some new institutes were established, including the Korean Institute of Chemical Technology.

South Korean science and technology is characterized by many close associations between academe and industry. The first was the Korean Genetic Research Association, founded in 1982. In 1988, 44 such associations were sponsored by 862 member companies.

Although all this association between academe and industry might indicate successful transfer of re-

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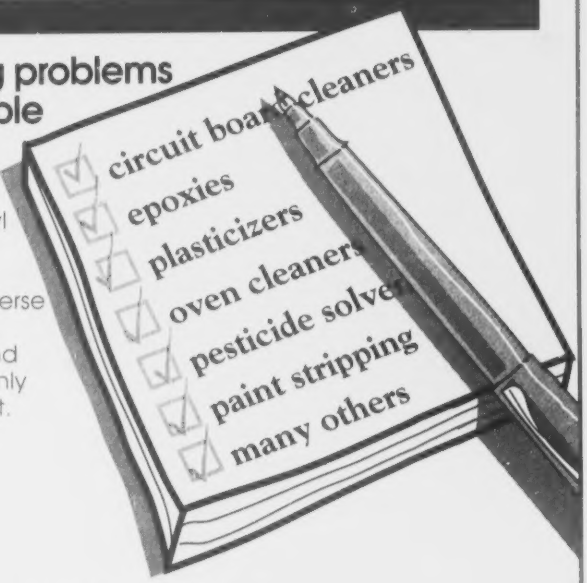

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search to products, statistics indicate economic development actually is slowing. In 1989, South Korea realized further economic development was impossible without dramatic growth in science and technology. Thus, the government enacted legislation to augment scientific and technical education.

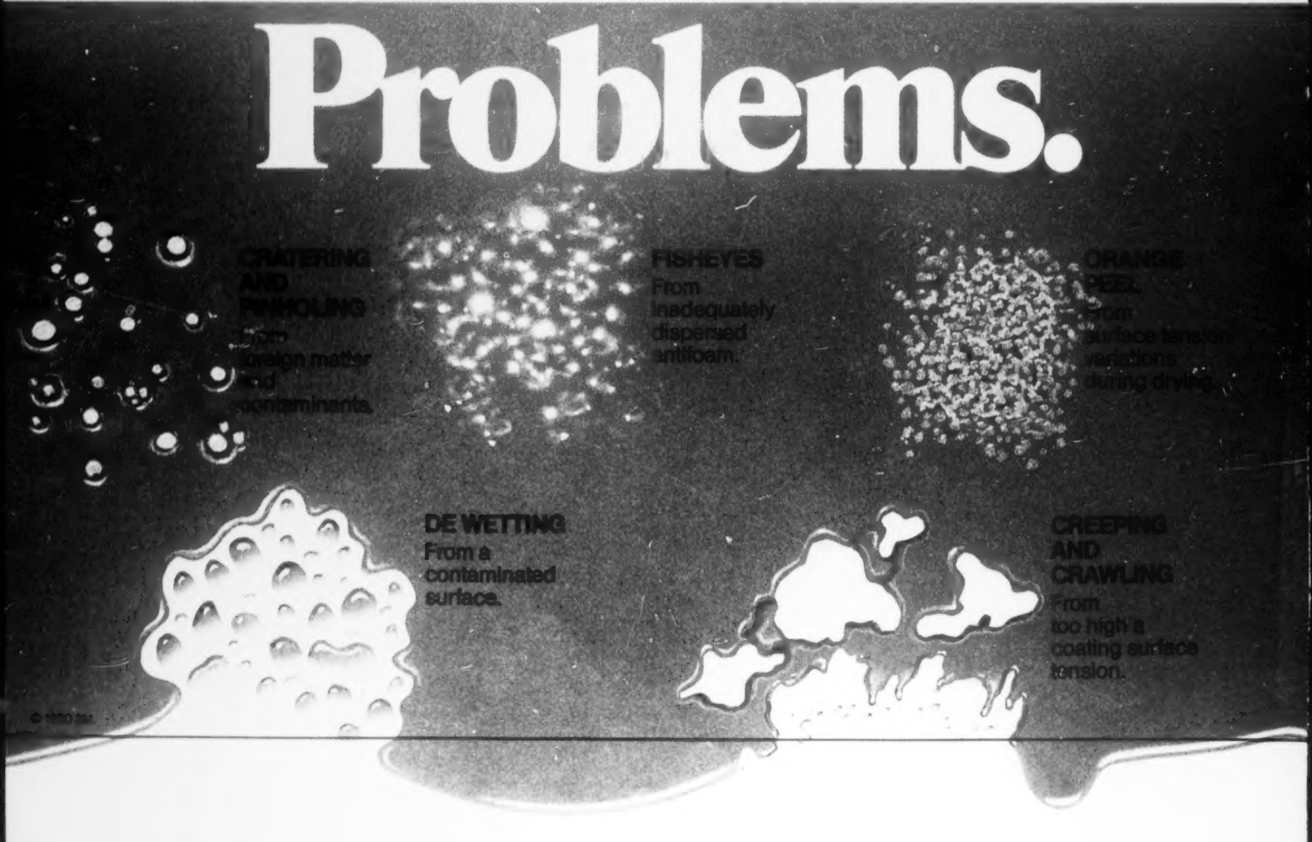
South Korea's very limited natural resources, a problem it has in common with the other "dragons," means that its economic lifeblood is imported technology, along with the technical development, through education, of its own people.

In retrospect, attendees of the conference note, South Korea should have invested more generously in science and technical education a generation ago. This is now being done, but some believe it's coming too late to have an immediate effect. The new projections for South Korea call for an average annual growth of 7.5% in GNP for the five-year period beginning in 1992. The corresponding per-capita wealth should be $11,000 in 1996. The total trade volume is projected to be $153 billion with a $3 billion deficit in 1992. By 1996, the total trade volume is projected to be $270 billion, with a surplus of $7.5 billion. Chu thinks South Korea's five-year economic plan is a bit optimistic. But if it all comes to pass, he suggests it will be more because of South Korean national grit than anything else.

In Taiwan, the situation is somewhat better. Jin-Fu Chang, a professor at National Taiwan University of Taipei, mentions a new national project aimed at making Taiwan a developed country in the next six years. This will require technical education to be closely integrated with national aims. Already in place is a centralized educational system with rather rigid specifications for the selection of university students. Taiwan has public and private universities, although the former dominate the picture. The public universities tend to emphasize graduate education more than the private universities. Chang believes the quality of the faculties is good and improving. As evidence of this, he notes that more and more university graduates are staying in Taiwan for graduate studies.

The Taiwanese problems cited by Chang are somewhat reminiscent of those in South Korea. Classes are large but the number of faculty is not adequate. Cooperation between academia and industry is lacking. At universities, the publish-or-perish syndrome is acute and the academic pay structure is poor. These problems, Chang says, are slowly being addressed.

Of greater long-term consequence is the character of the students and the curriculum. Chang was one of many speakers who noted the lack of "working ethics" among graduates. He does not mean the absence of inherent honesty but, instead, the tendency to strive for position rather than the production of results.


Problems.
CRATERING AND PINHOLING
From foreign matter and contaminants.
FISHEYES
From inadequately dispersed antifoam.
ORANGE PEEL
From surface tension variations during drying.
DE WETTING
From a contaminated surface.
CREEPING AND CRAWLING
From too high a coating surface tension.

Several attendees, in private conversations, acknowledged the difficulty of inculcating in students—particularly undergraduates—the idea that one has to constantly produce to justify his or her position.

Attendees noted there is a superficial contradiction here, as Asian students traditionally are noted for the intensity and devotion of their study efforts, an attitude nurtured by parents and society. The problem, apparently, is not that students are unwilling to work. Quite the contrary. But educators are realizing that a substantial change in motivation may be necessary.

A frequently repeated topic was the perceived need for more training in the social sciences and humanities. This has been a subject of great debate among western engineering educators for many years. It has now become a matter of more than academic interest: It is seen as necessary to better fill the needs of international—that is, globalized—commerce.

Probably the most enigmatic of the Pacific Rim countries is China. Only after the death of Mao Zedong was there substantial and demonstrable change in internal access to this nation. The new constitution of 1978 provided a starting point for reform of economics, education, science, and technology. Most information about China's educational organizations date from that time.

Wu Yongshi, president of Tianjin University, notes that, in the 1980s, reforms resulted in an annual GNP growth rate of 9%; growth in national income was 8.7%. Since the national well-being depends on science and technology, much attention has been paid to the training of scientists and engineers. This is reflected in increases in students, faculty, and researchers, as well as in increased funding.

A highly centralized plan has been set up to organize China's educational establishment. The regional distribution of universities tends to follow the centers of population, which are for the most part along the coast.

The distribution of subject matter generally follows the government's perceived needs. Politics, law, finance, and economics are being enhanced, but the study of science and engineering has developed most rapidly. An important event was the issuing of the 1980 regulations of academic degrees in China. These placed special emphasis on graduate degrees. In the 1980s, China produced 6000 doctoral students and 177,000 M.S. students. Two- and three-year junior colleges also have been established to train the requisite mechanics, technicians, and lower level professionals. The numbers of graduate students, undergraduates, and junior college students are adjusted to conform to the prescribed ratio 7:100:56.3.

Procedures for gaining admission to China's various colleges and universities are strictly controlled by

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Education reform in China followed some intense political activity. In 1951–52, China emulated the Soviet Union's educational structure because of the close ties that existed between the two countries. As in the U.S.S.R., Chinese colleges and universities were of three types: comprehensive universities; polytechnic universities; and independent, single-subject universities, such as special universities for the iron and steel industry. Most of the interest with respect to science and technology centers on 14 polytechnic universities administered by the State Education Commission. These are the most prestigious in China and they usually get the bulk of the funding for research and special projects.

When China began sending large numbers of students and exchange professors abroad in the 1980s, they returned with new educational perspectives. For example, they came back realizing that while Chinese students usually had good grounding in the basic sciences, they were often less than well developed in what Wu calls "creative abilities." This perceived lack was considered by some conference attendees as the recognition that endless learning by rote had left no time for cultivation of the imagination. Greater cultivation of creative abilities has now been orchestrated into more recent Chinese curricula.

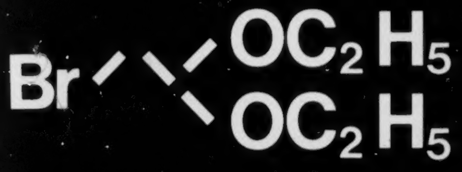
The highly compartmentalized, standardized unit training of the past has been changed to a more diversified curriculum that often takes students "across departments and, occasionally, to other universities." This liberalization of the curriculum sometimes results in graduates obtaining "bi-bachelor degrees."

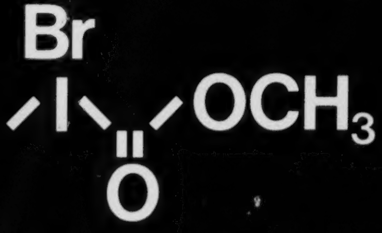
China also has altered the structure of research universities to include new norms. For instance, the allowable percentage of graduate students has been raised to 30% of the total student population. Full professors and associate professors should comprise up to 45% of the entire faculty roster. Allocation of funds to research is set to be at least equal to the funds allocated to teaching.

Reflection on the problems discussed at the conference suggests that the impetus to improve scientific and technical education may be great, but that cultural and social barriers may be greater than imagined.

It is also apparent that the great commercial tide that swept along both the little dragons and the bigger ones in the 1970s and 1980s was largely powered by the indigenous efforts of the people, aided by a favorable international investment climate. A recurring theme in all the presentations was that improvements require more effort and expense than first believed. As one engineer put it, "It's harder to stay in the race than to get into it in the first place." □

Brominated Derivatives





Bromoacetaldehyde Diethyl Acetal (BADA):
BADA is a very useful intermediate, as under alkaline conditions, the bromine site is reactive whereas, under acid conditions, the acetal groups become reactive. Therefore, BADA is especially useful for 2-step ring closure reactions for connecting heteroatoms. 2-Amino-5 Nitrothiazole, and its derivatives, which are useful antibiotics or disinfectants, are commonly prepared using BADA.

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Facts & Figures for Chemical R&D

Bette Hileman and **Janice R. Long**,
C&EN Washington, and
Ward Worthy, C&EN Chicago

Modest growth in R&D funding in the U.S. is expected in 1991. The National Science Foundation estimates total funding will reach about $152 billion this year, an increase of about $6 billion, or 4%, over 1990 levels. When adjusted for inflation, that represents a 2% gain over the previous year.

Thus, 1991 looks to be a continuation of the pattern of R&D spending of the past five years. Since 1986, overall R&D spending in the U.S. has been rising at an annual rate of somewhat less than 2%, after adjusting for inflation, or 7% for the entire period. This is down sharply from the 5 to 9% annual growth rates R&D spending enjoyed earlier in the decade, when real R&D spending grew 40% from 1980 to 1985.

And even the modest growth expected in 1991 is not being fueled primarily by federal government support of R&D, which, in real terms, is expected to decline 1% this year, to $66 billion. Such growth as is occurring is being financed primarily by industry, which will increase its support from $75 billion in 1990 to $78 billion in 1991, an increase, after adjusting for inflation, of about 2%. Universities and other nonprofit organizations are also doing what they can to offset the federal government's modest increases in R&D support: Universities' contributions to R&D are expected to rise from $4.5 billion in 1990 to $5.0 billion this year, and other nonprofit institutions are raising their support from $2.3 billion to $2.6 billion.

The biggest drop in R&D support comes from the Defense Department, which in 1991 will spend just under $37 billion on R&D, down, even in current dollars, from the $38 billion it spent in 1987. In 1987 32% of total R&D funds were spent on defense-related R&D; this year defense's share has dropped to 26%. Since most defense R&D is for development work, it's not surprising that this portion of total R&D has also declined. It received 63% of total R&D funds in 1987 but this year will account for only 61%. Basic research has picked up most of the balance, rising from 14% of total R&D spending in 1987 to 16% in 1991.

Like R&D spending itself, the fraction of gross national product spent on R&D in the U.S. rose steadily in the early 1980s but has now leveled off. Since 1985, it has been holding fairly steady at 2.7 to 2.8% of the value of all goods and

1 Overview

Where R&D funds come from and where they go. Who gets U.S. chemical patents and in what fields chemistry papers are published .... **Page 37**

2 Federal Government

Spending for R&D by the government as a whole and by various federal agencies, particularly in chemistry and chemical engineering. How funds are divided up among basic, applied, and developmental research .... **Page 43**

3 Industry

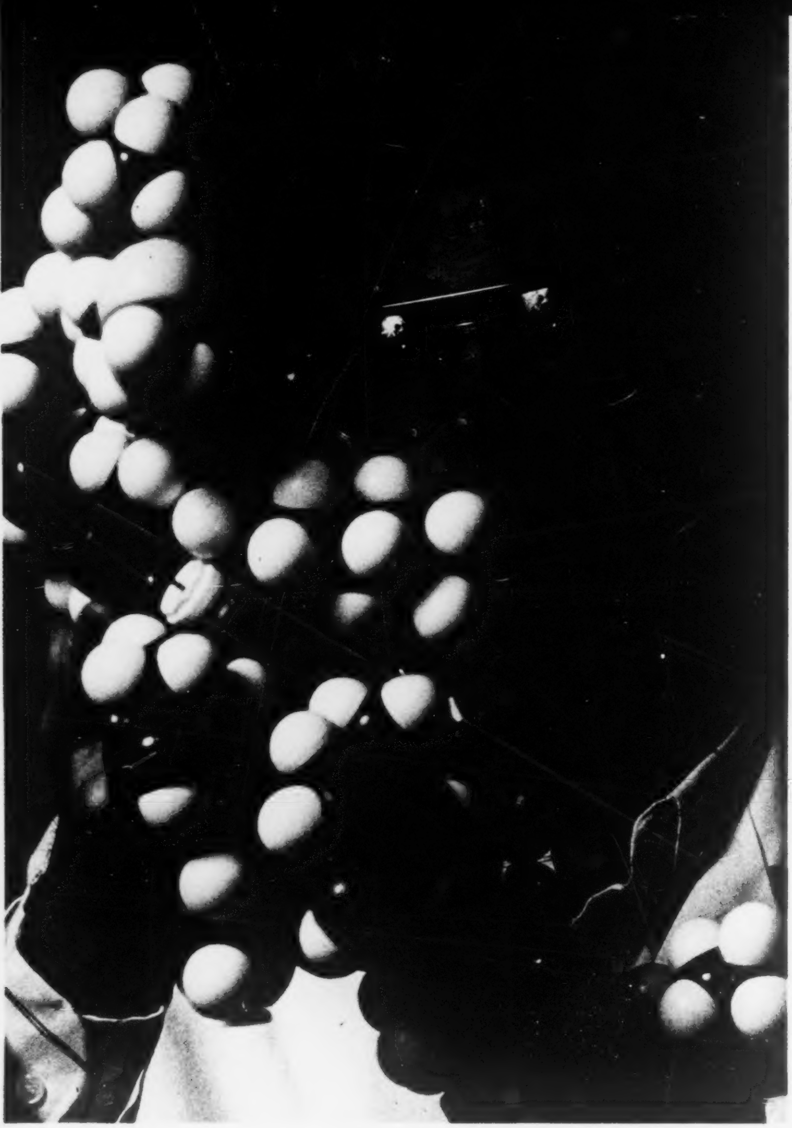
How much industry, especially the chemical industry, spends on R&D. Which industries hire chemists and which ones pay best .... **Page 53**

4 Universities & Colleges

Who funds academic R&D and which schools do the most. Who spends the most for chemistry and chemical engineering. Trends in equipment purchases, capital spending, and degrees awarded .... **Page 59**

5 International

R&D spending in the U.S. compared with other nations, especially Japan and Western European countries. Which countries publish most of the chemical literature .... **Page 69**



Bristol-Myers Squibb photo

services produced in the U.S. The share of GNP used for nondefense R&D has remained at 1.9 to 2.0% since 1983.

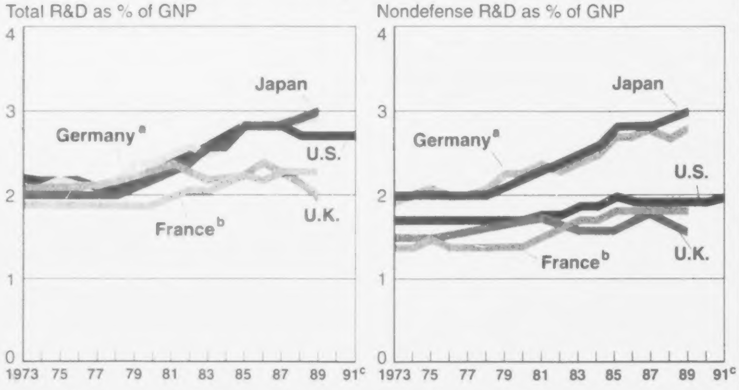
Share of GNP devoted to R&D is a useful measure for comparing R&D efforts in different countries, since it takes into account the relative economic base of different countries. By this measure, both Japan, at 3.0% of GNP, and what was then West Germany, at 2.9%, spent larger fractions of their economic resources on R&D than did the U.S. in 1989, the most recent year for which comparative data are available. However, in that year France, at 2.3%, spent considerably less than the U.S.

When only defense R&D is considered, the differences between countries are even greater. In 1989 Japan spent only 1% of its total R&D on defense, and West Germany spent 5%. These levels contrast greatly with the 21% spent by France and the U.K. on defense, and the 29% used by the U.S.

In absolute terms, the U.S. R&D effort dwarfs that of any other country. It spends 2.4 times as much as its closest competitor—Japan—and five times as much as Germany. But R&D programs in Japan and Germany are expanding faster than they are in the U.S. For example, in 1989, Japan's R&D funding grew 9% and West Germany's rose 6% in real terms over funding levels in 1988, while U.S. expenditures rose only 1%.

Japan is catching up to the U.S. in several other ways as well. The share of U.S. chemical patents awarded to Japanese citizens, corporations, and government agencies rose from 13% of the total in 1981 to 21% in 1990, while the share claimed by U.S. citizens and organizations fell 7% over the same period. The U.S. share of chemical literature abstracted by Chemical Abstracts Service has remained steady at about 27% since 1974, but Japan's share has

Nondefense R&D takes virtually all R&D share of GNP in Germany and Japan, leaving little for defense

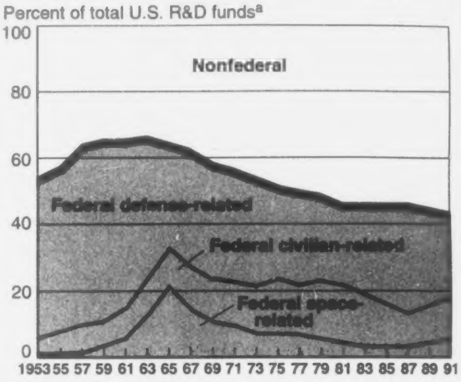


a Data are for former West Germany. b French data are based on gross domestic product, consequently percentages may be slightly overstated. c 1990 and 1991 percentages are C&EN estimates. **Source:** National Science Foundation risen from 7.4% in 1974 to 12.1% in 1990. In recent years, the number of scientists and engineers engaged in R&D has also been increasing faster in Japan than in the U.S.

Several other measures reflect the health of the overall R&D effort in the U.S. vis-à-vis the rest of the world. In the U.S., the total number of graduate students in all sciences and engineering has increased at an average rate of 2% a year since 1979, but the number of foreign graduate students without permanent visas has been rising much faster. In 1983, foreign students represented only 26% of the total; in 1989, they were 33%. After graduation, some of these students remain in the U.S., but many return to their native countries.

In chemistry and chemical engineering, these trends are even more striking. In chemistry, foreign graduate students escalated from 23% of the total in 1983 to 35% in 1989, and in chemical engineering from 38% to 49% over the same period.

Defense share of U.S. R&D funds has generally declined since 1963

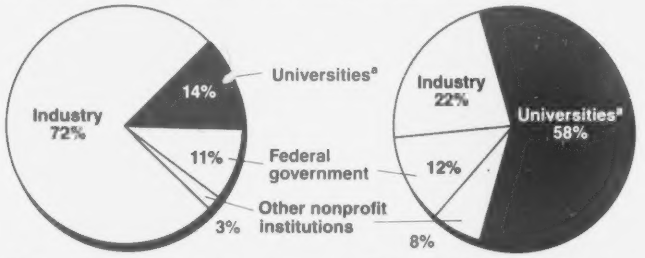


Note: Total R&D funds for 1991 = $152 billion.
Source: National Science Foundation

Funding for research in chemistry at universities has risen at a fairly constant rate of about 11% annually during the past decade, matching the annual rate by which overall R&D funding increased at universities. Funding for R&D in chemical engineering has been rising 12% per year since 1980. The federal government provides most of these funds. In 1989, it supplied $424 million, or 70%, of the $610 million spent by universities on chemical research.

According to NSF, the federal government will spend $832 million for research in chemistry in all sectors in the fiscal year that ends Sept. 30, down 1% from the $839 million it spent in fiscal 1990. Four agencies provide most of these funds—the Department of Energy 23%, NSF 18%, DOD 17%, and Health & Human Services 15%. At universities, NSF, HHS, and DOD together provide 83% of total federal funds for chemical research.

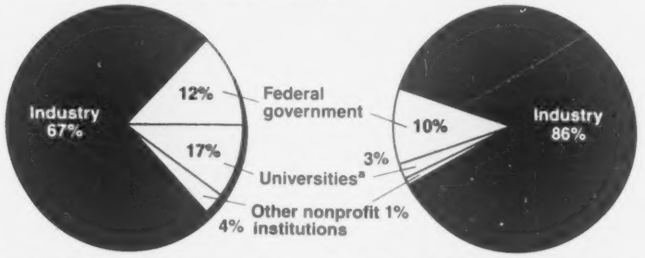
Universities perform only 14% of total R&D even though they do 58% of basic research . . .



Estimated 1991 total R&D spending = $152 billion

Estimated 1991 basic research spending = $24 billion

. . . industry does 67% of applied research and performs all but 14% of development



Estimated 1991 applied research spending = $35 billion

Estimated 1991 development spending = $93 billion

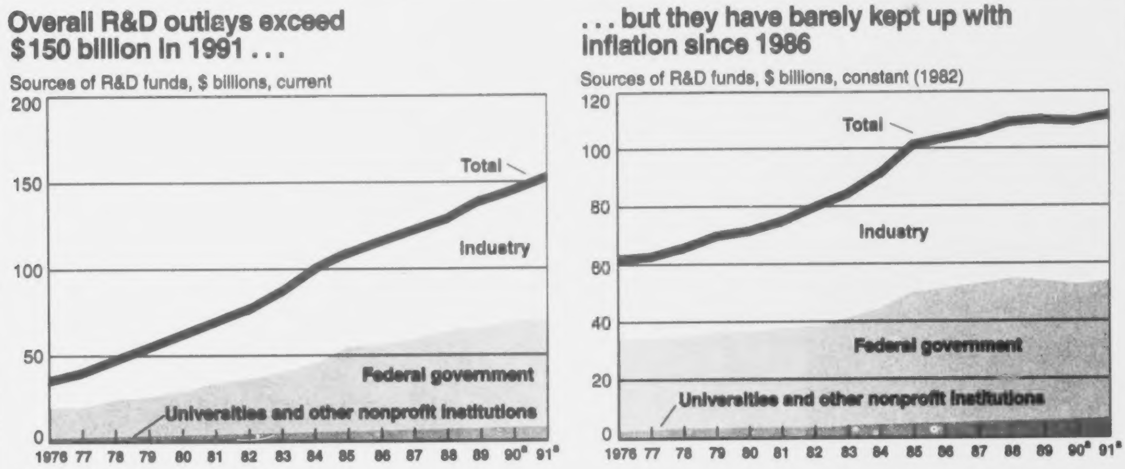
a Includes associated federally funded R&D centers **Source:** National Science Foundation

In fiscal-year 1992, total government funding for R&D is expected to grow at a fairly healthy pace. Congressional appropriations call for an 18% boost in NSF's research budget, to $2.64 billion, and a 13% increase for DOE, to $6.16 billion. Chemical research is likely to benefit from these hikes because both agencies are large supporters of such research.

In industry, the chemicals and allied products industry, not surprisingly, is the chief supporter of chemical R&D. In 1990, it spent an estimated $12.6 billion for R&D, 11% more than in 1989. Roughly three quarters of these funds support research in chemical R&D. Drug companies increased their R&D spending 13% to an estimated $6.1 billion. By contrast, overall industrial R&D increased only about 3%.

Much of the information for this Special Report is taken from statistical studies by NSF's Division of Science Resources Studies. These studies are available from the National Science Foundation, Division of Science Resources Studies, Office of the Director, 1800 G St., N.W., Washington, D.C. 20402, phone (202) 634-4634. □

Funding Continues To Grow at a Slow Pace



Overall R&D outlays exceed $150 billion in 1991 . . .

Sources of R&D funds, $ billions, current

. . . but they have barely kept up with inflation since 1986

Sources of R&D funds, $ billions, constant (1982)

a Preliminary. Source: National Science Foundation

SOURCES OF R&D FUNDS: Industry contributes more than half, universities' share rises sharply

												Annual change	
$ Billions, current	1991a	1990a	1989	1988	1987	1986	1985	1984	1983	1982	1981	1990–91	1981–91
Industry	$ 78.1	$ 74.7	$ 71.8	$ 67.0	$ 62.6	$ 61.1	$ 58.0	$ 52.2	$ 45.8	$ 40.7	$ 35.9	5%	8%
Federal government	66.0	64.0	62.7	61.5	57.9	54.3	52.1	45.6	40.8	36.6	33.4	3	7
Universities and colleges	5.0	4.5	3.9	3.5	3.2	2.8	2.4	2.1	1.9	1.7	1.6	11	12
Other nonprofit institutions	2.6	2.3	2.1	1.8	1.6	1.4	1.3	1.2	1.1	1.0	1.0	13	10
TOTAL	$151.6	$145.5	$140.5	$133.7	$125.4	$119.5	$113.8	$101.1	$ 89.1	$ 80.0	$ 71.9	4%	8%
ANNUAL CHANGE	4%	4%	5%	7%	5%	5%	13%	13%	11%	11%	15%		
$ Billions, constant 1982													
Industry	$ 57.9	$ 56.8	$ 56.8	$ 55.2	$ 53.3	$ 53.6	$ 52.3	$ 48.5	$ 43.6	$ 40.7	$ 38.3	2%	4%
Federal government	49.0	48.7	49.6	50.6	49.2	47.6	46.9	42.3	39.3	36.6	35.7	−1	3
Universities and colleges	3.7	3.4	3.1	2.9	2.7	2.4	2.1	1.9	1.8	1.7	1.7	9	8
Other nonprofit institutions	1.9	1.7	1.6	1.5	1.4	1.2	1.2	1.1	1.1	1.0	1.0	10	6
TOTAL	$112.5	$110.6	$111.1	$110.2	$106.6	$104.9	$102.5	$ 93.8	$ 85.6	$ 80.0	$ 76.6	2%	4%
ANNUAL CHANGE	2%	−1%	1%	3%	2%	2%	9%	9%	7%	4%	5%		

Note: Constant-dollar values are calculated by C&EN from NSF data. Totals do not add up because of rounding. a Preliminary figures, NSF estimates. **Source:** National Science Foundation

PERFORMERS OF R&D: Government's share of total R&D falls in real terms

$ Billions, current	1991[a]	1990[a]	1989	1988	1987	1986	1985	1984	1983	1982	1981	Annual change 1990–91	1981–91
Industry	$108.4	$104.2	$101.6	$ 97.8	$ 92.2	$ 87.8	$ 84.2	$ 74.8	$65.3	$58.7	$51.8	4%	8%
Federal government	16.4	16.1	15.1	14.3	13.4	13.5	12.9	11.6	10.6	9.1	8.4	2	7
Universities and colleges	17.2	16.0	15.0	13.5	12.2	10.9	9.7	8.6	7.9	7.3	6.6	8	10
University-associated FFRDCs[b]	4.9	4.8	4.7	4.5	4.2	3.9	3.5	3.2	2.7	2.5	2.5	1	7
Other nonprofit institutions	4.7	4.4	4.1	3.6	3.4	3.4	3.4	3.0	2.7	2.4	2.3	8	7
TOTAL	**$151.6**	**$145.5**	**$140.5**	**$133.7**	**$125.4**	**$119.5**	**$113.6**	**$101.1**	**$89.1**	**$80.0**	**$71.9**	**4%**	**8%**
$ Billions, constant 1982													
Industry	$ 80.4	$ 79.2	$ 80.4	$ 80.6	$ 78.5	$ 77.2	$ 75.9	$ 69.4	$62.8	$58.7	$55.1	1%	4%
Federal government	12.2	12.2	11.9	11.7	11.4	11.8	11.6	10.7	10.2	9.1	9.0	−1	3
Universities and colleges	12.8	12.2	11.8	11.1	10.3	9.5	8.7	8.0	7.6	7.3	7.3	5	6
University-associated FFRDCs[b]	3.6	3.7	3.7	3.7	3.6	3.4	3.2	2.9	2.6	2.5	2.7	−1	3
Other nonprofit institutions	3.5	3.3	3.2	2.9	2.9	2.9	3.1	2.8	2.6	2.4	2.4	5	4
TOTAL	**$112.5**	**$110.6**	**$111.1**	**$110.2**	**$106.8**	**$104.9**	**$102.5**	**$ 93.8**	**$85.8**	**$80.0**	**$76.6**	**2%**	**4%**

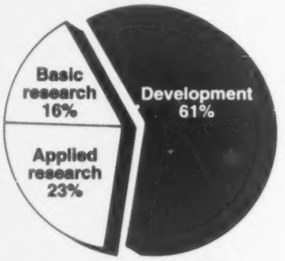
Note: Constant-dollar values are calculated by C&EN based on NSF data. Totals do not add up because of rounding. a Preliminary figures, NSF estimates. b Federally funded R&D centers.
Source: National Science Foundation

U.S. CHEMICAL PATENTS: Total dropped 4% last year, those of U.S. origin fell 6%

Number of patents issued	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	Total 1981–90
U.S. origin	**12,996**	**13,786**	**11,247**	**11,394**	**10,500**	**11,531**	**11,501**	**10,554**	**10,613**	**12,687**	**116,809**
to U.S. corporations	11,214	12,032	9,849	9,897	9,191	10,172	10,117	9,143	9,172	10,973	101,760
to U.S. government	310	295	260	325	290	322	376	330	311	364	3,183
to individuals in the U.S.	1,296	1,297	1,014	1,046	925	966	933	985	1,029	1,276	10,787
to foreign-owned corporations in the U.S.	176	162	124	126	94	51	75	96	101	74	1,079
Foreign origin	**12,762**	**13,139**	**10,544**	**10,257**	**9,110**	**9,695**	**8,997**	**8,065**	**8,017**	**9,619**	**100,205**
to U.S.-owned corporations abroad	1,095	1,130	854	847	756	863	833	701	730	896	8,725
to foreign corporations	10,789	11,105	8,936	8,657	7,677	8,085	7,443	6,710	6,517	7,855	83,774
to foreign governments	151	176	170	200	148	161	166	133	165	100	1,570
to foreign individuals	727	728	584	553	529	566	555	521	605	768	6,136
TOTAL	**25,758**	**26,925**	**21,791**	**21,651**	**19,610**	**21,226**	**20,498**	**18,619**	**18,630**	**22,306**	**217,014**
% FOREIGN	**49.5%**	**48.8%**	**48.4%**	**47.4%**	**46.5%**	**45.7%**	**43.8%**	**43.3%**	**43.0%**	**43.1%**	**46.2%**

Note: Includes patents issued in those technology subclasses that the U.S. Patent & Trademark Office classifies as chemical. **Source:** U.S. Patent & Trademark Office

More than 60% of R&D funds go to development



Estimated total 1991 R&D spending = $152 billion

Source: National Science Foundation

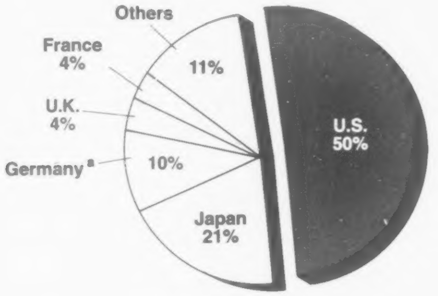
RECIPIENTS OF U.S. CHEMICAL PATENTS: Japan claims a steadily growing share

% of patents	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	Total 1981–90
U.S. origin	**50%**	**51%**	**52%**	**53%**	**54%**	**54%**	**56%**	**57%**	**57%**	**57%**	**54%**
Foreign origin	**50**	**49**	**48**	**47**	**46**	**46**	**44**	**43**	**43**	**43**	**46**
Japan	21	20	20	19	19	18	16	15	14	13	18
Germany[a]	10	10	11	10	10	10	10	11	11	11	11
U.K.	4	4	4	4	4	4	4	4	4	4	4
France	4	3	4	4	3	3	3	3	4	4	4
Switzerland	2	2	2	2	2	2	2	2	2	2	2
Canada	2	2	2	1	1	2	1	1	1	1	1
Italy	2	2	1	1	1	1	1	1	1	1	1
Netherlands	1	1	1	1	1	1	1	1	1	1	1
Sweden	1	1	1	1	1	1	1	1	1	1	1
Belgium	1	1	1	1	1	1	1	1	1	1	1
U.S.S.R.	—	—	—	—	—	—	—	—	—	1	—

Note: Includes patents issued in those technology subclasses that the U.S. Patent & Trademark Office classifies as chemical. a Patents prior to October 1990 were issued to West Germany. **Source:** U.S. Patent & Trademark Office

1 R&D Overview

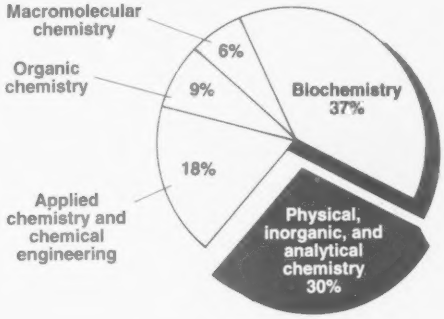
Only half of U.S. chemical patents originate in the U.S.



1990 total U.S. chemical patents issued = 25,758

a Before October 1990 these patents were issued to West Germany.
Source: U.S. Patent & Trademark Office

Nearly one third of chemistry papers are in physical, inorganic, and analytical



1990 total[a] = 394,945

a Number of abstracts of papers published in *Chemical Abstracts*.
Source: Chemical Abstracts Service

PATENT ACTIVITY OF U.S. COMPANIES: Most drug firms were granted fewer patents last year

Number of patents issued	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	Total 1981–90
CHEMICAL COMPANIES											
Du Pont[a]	533	495	437	449	371	395	416	387	331	430	**4,244**
Dow Chemical	400	431	421	469	371	335	328	246	277	260	**3,538**
Ciba-Geigy	409	346	279	286	244	305	290	244	281	345	**3,029**
Union Carbide	43	132	141	159	208	242	231	182	202	262	**1,802**
American Cyanamid	136	114	101	107	92	115	111	128	129	188	**1,221**
PPG Industries	100	112	118	118	124	128	137	137	177	189	**1,340**
Dow Corning	122	105	82	58	68	55	52	37	35	50	**664**
Ethyl	108	87	51	48	77	105	76	44	31	43	**670**
Air Products	98	119	70	85	61	80	60	49	54	32	**708**
Monsanto	84	87	76	91	110	100	138	136	131	211	**1,164**
Olin	74	80	59	58	81	117	112	85	80	80	**826**
W. R. Grace	105	111	61	44	43	45	57	52	49	68	**635**
Hercules	35	46	32	50	43	41	39	37	30	52	**405**
Rohm & Haas	32	32	18	22	33	31	37	55	49	77	**386**
International Flavors & Fragrances	40	31	24	38	76	104	95	87	87	96	**678**
GAF	—	50	23	15	12	23	19	21	32	47	**242**
TOTAL[b]	**2319**	**2378**	**1993**	**2097**	**2014**	**2221**	**2198**	**1927**	**1975**	**2430**	**21,552**
ANNUAL CHANGE	**−2%**	**19%**	**−5%**	**4%**	**−9%**	**1%**	**14%**	**−2%**	**−19%**	**10%**	
DRUG COMPANIES											
Merck	134	173	125	123	103	105	135	115	135	160	**1,307**
Warner-Lambert	108	117	113	118	101	73	49	34	25	37	**775**
Pfizer	82	79	63	67	72	72	89	61	72	92	**749**
Hoffmann-LaRoche	78	93	59	86	84	74	78	90	118	124	**884**
Eli Lilly	73	75	68	85	82	107	80	74	104	112	**860**
American Home Products	66	78	69	46	38	49	32	24	43	52	**497**
Abbott Laboratories	64	39	39	30	29	36	32	32	50	64	**415**
Squibb	61	66	74	75	70	74	53	37	56	62	**628**
SmithKline Beckman	29	62	56	54	27	43	68	59	66	59	**523**
Upjohn	25	30	15	26	66	66	107	73	122	337	**867**
TOTAL[b]	**720**	**812**	**681**	**710**	**672**	**699**	**723**	**598**	**791**	**1099**	**7,505**
ANNUAL CHANGE	**−11%**	**19%**	**−4%**	**6%**	**−4%**	**−3%**	**21%**	**−24%**	**−28%**	**11%**	

Note: Includes U.S. chemical and drug companies and U.S. subsidiaries of foreign companies that have received more than 1000 U.S. patents since 1962. **a** Includes patents issued to Conoco, acquired in 1981, for all years. **b** These totals include patents issued to companies in this table only. **Source:** U.S. Patent & Trademark Office

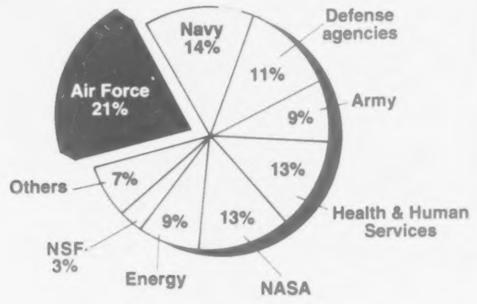
ABSTRACTS OF PAPERS IN *CHEMICAL ABSTRACTS*: Biochemistry's dominant share declining

	1990	1989	1988	1987	1986	1985	1984	1983	1980	Change 1980–90
BIOCHEMISTRY	36.9%	39.2%	39.7%	40.5%	40.4%	40.5%	40.5%	38.3%	39.8%	−2.9%
% of all biochemistry abstracts										
Pharmacology	11.7	12.6	12.7	12.6	12.2	12.3	11.6	11.8	12.0	−0.3
Mammalian hormones[a]	11.5	12.0	12.0	12.2	12.5	12.3	12.4	12.9	6.0	5.5
Mammalian biochemistry[a]	10.5	10.7	10.8	11.1	10.8	11.1	11.3	11.1	16.3	−5.8
Biochemical genetics[b]	10.1	7.9	7.6	6.7	6.1	5.2	4.2	3.8	—	—
Immunochemistry	6.8	6.3	5.8	5.8	6.1	5.3	4.8	4.2	3.1	3.7
Toxicology	6.7	7.8	7.9	8.3	7.8	7.9	8.0	8.5	8.3	−1.6
Enzymes	6.1	6.1	6.1	5.4	5.6	5.6	5.8	6.1	6.2	−0.1
Microbial biochemistry[a]	5.4	5.1	4.8	5.1	5.7	5.7	5.2	5.1	5.2	0.2
General biochemistry	5.2	5.1	5.3	4.6	4.7	4.9	5.3	5.8	6.6	−1.4
Plant biochemistry[a]	5.1	4.6	5.0	5.3	5.2	5.5	6.2	5.9	5.7	−0.6
Biochemical methods	4.7	5.1	5.1	4.8	5.0	4.9	4.9	4.9	5.5	−0.8
Others	16.2	16.7	16.9	18.1	18.3	19.3	20.3	19.9	25.1	−8.9
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	—
PHYSICAL, INORGANIC, AND ANALYTICAL CHEMISTRY	30.3%	29.0%	28.8%	29.0%	29.8%	29.8%	28.8%	29.6%	28.6%	1.7%
% of all physical, inorganic, and analytical chemistry abstracts										
Nuclear chemistry	17.1	19.4	17.8	19.5	19.9	21.8	22.2	22.5	23.2	−6.1
Spectra	16.9	18.1	20.0	20.4	20.0	18.4	18.0	17.6	18.2	−1.3
Electric phenomena	13.2	13.9	12.5	10.9	10.8	10.8	10.8	10.0	11.2	2.0
Analytical chemistry	7.9	5.1	5.7	5.9	6.8	6.1	6.3	6.2	5.6	2.3
General physical chemistry	7.7	6.9	7.2	7.9	7.0	6.9	6.9	7.3	7.1	0.6
Crystallography and liquid crystals	7.3	7.8	7.0	7.1	7.0	7.5	7.8	8.3	8.1	−0.8
Others	29.9	26.8	29.8	28.3	28.5	28.5	28.0	28.1	26.6	3.3
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	—
APPLIED CHEMISTRY AND CHEMICAL ENGINEERING	18.2%	18.1%	18.6%	18.0%	18.2%	18.4%	17.6%	19.4%	18.9%	−0.7%
% of all applied chemistry and chemical engineering abstracts										
Metals and alloys	24.5	22.1	21.7	20.6	20.8	20.0	18.9	19.1	22.0	2.5
Water, wastes, and pollution	18.8	17.8	20.4	20.4	21.9	20.2	21.0	19.6	22.5	−3.7
Ceramics	9.4	9.1	6.7	6.3	5.8	5.6	5.1	5.4	4.1	5.3
Unit operations and processes	9.2	10.3	8.0	9.0	7.1	7.5	7.0	7.5	6.0	3.2
Pharmaceuticals and pharmaceutical analysis	8.2	7.8	7.6	7.8	8.2	8.0	7.0	6.5	5.5	2.7
Fossil fuels, derivatives, and related products	8.0	8.7	8.8	9.6	9.0	10.1	10.1	10.3	8.9	−0.9
Mineralogical and geological chemistry	7.8	9.3	11.8	11.2	12.0	12.5	14.6	14.1	15.7	−7.9
Others	14.1	14.9	15.0	15.1	15.2	16.1	16.3	17.5	15.3	−1.2
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	—
ORGANIC CHEMISTRY	8.7%	7.8%	7.3%	6.9%	5.9%	6.4%	7.6%	7.3%	7.4%	1.3%
% of all organic chemistry abstracts										
Physical organic chemistry	21.2	25.9	23.0	23.9	27.3	30.6	32.0	30.5	38.8	−17.6
Organometallic and organometalloidal compounds	20.4	18.4	15.7	16.1	18.3	16.2	17.1	16.3	8.2	12.2
Heterocyclic compounds[a]	17.4	16.1	18.8	19.9	15.0	16.1	15.6	16.2	17.3	0.1
Carbohydrates	7.4	6.5	8.1	5.6	7.8	5.7	5.7	5.8	5.7	1.7
Aromatic compounds[a]	7.1	6.9	7.2	7.7	7.3	6.3	6.3	7.1	7.8	−0.7
Amino acids, peptides, and proteins[a]	6.0	4.5	5.8	4.3	3.9	4.6	4.8	4.5	3.7	2.3
Biomolecules and their synthetic analogs[b]	5.9	5.8	6.1	5.8	5.0	4.9	4.4	4.5	—	—
Aliphatic compounds[a]	3.3	3.6	4.1	4.9	4.4	4.2	3.6	4.3	6.0	−2.7
Others	11.3	12.3	11.2	11.8	11.0	11.4	10.5	10.8	12.5	−1.2
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	—
MACROMOLECULAR CHEMISTRY	5.9%	5.9%	5.6%	5.6%	5.7%	4.9%	5.5%	5.4%	5.3%	0.6%
% of all macromolecular chemistry abstracts										
Synthetic high polymers	38.6	34.4	34.8	35.2	34.1	34.1	34.0	34.4	27.0	11.6
Plastics manufacture and uses	23.3	25.1	23.7	23.6	23.8	25.3	24.2	24.4	28.1	−4.8
Industrial organic chemicals, leather, fats, and waxes	8.4	8.1	6.8	5.6	4.6	4.4	4.8	4.8	—	—
Cellulose, lignin, paper, and other wood products	7.6	9.2	9.6	8.8	9.8	9.1	9.6	9.1	10.9	−3.3
Textiles	6.7	7.2	7.3	8.1	8.8	8.2	7.3	7.9	10.1	−3.4
Coatings, inks, and related products	5.2	5.6	5.7	5.8	7.2	7.2	7.8	6.6	7.4	−2.2
Synthetic elastomers and natural rubber	4.8	5.6	6.7	7.2	6.7	6.8	7.3	7.5	8.4	−3.6
Others	5.4	4.8	5.4	5.7	5.0	4.9	5.0	5.3	7.9	−2.5
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	—

How to read this table: Using biochemistry as an example, in 1990 36.9% of all the papers abstracted by Chemical Abstracts Service are in the various subdisciplines of biochemistry; 11.7% of all abstracts in biochemistry, in turn, are in the subdiscipline of pharmacology, and so on. **a** Definition of section changed in 1982. **b** New section in 1982. **Source:** Chemical Abstracts Service

Defense Funding Still Large, but Shrinking

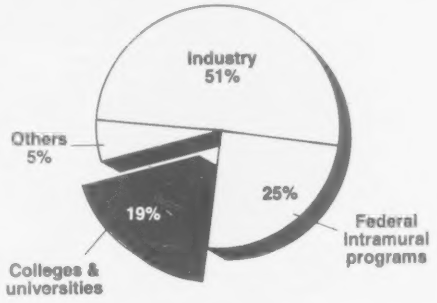
A fifth of federal R&D funds comes from the Air Force . . .



Estimated fiscal 1991 total federal R&D obligations = $66.1 billion

Source: National Science Foundation

. . . and about a fifth of federal R&D is performed by academia



Estimated fiscal 1991 total federal R&D obligations = $66.1 billion

FEDERAL OBLIGATIONS FOR R&D: Growth in civilian R&D programs outpacing defense

$ Millions	1991^a	1990^a	1989	1988	1987	1986	1985	1984	Annual change 1990–91	Annual change 1984–91
Defense	$36,918	$35,899	$37,577	$35,415	$35,232	$32,938	$29,792	$25,373	3%	6%
Air Force	13,583	13,720	15,237	15,034	15,348	13,594	13,261	12,092	−1	2
Navy	9,358	9,589	9,666	9,514	9,508	9,650	9,127	7,606	−2	3
Army	6,228	5,593	5,659	4,806	5,020	4,809	4,571	4,226	11	7
Defense agencies	7,348	6,744	6,859	5,833	5,220	4,767	2,782	1,392	9	27
Health & Human Services	8,888	8,457	7,903	7,158	6,609	5,658	5,451	4,831	5	9
National Institutes of Health	7,473	7,141	6,778	6,291	5,853	5,005	4,828	4,257	5	8
Alcohol, Drug Abuse & Mental Health Administration	920	821	696	555	476	396	378	337	12	15
NASA	8,322	6,635	5,394	4,330	3,787	3,420	3,327	2,822	25	17
Energy	6,008	5,698	5,193	5,036	4,757	4,688	4,996	4,674	5	4
NSF	1,983	1,768	1,670	1,532	1,471	1,353	1,346	1,203	12	7
Agriculture	1,158	1,104	1,038	1,017	948	929	943	866	5	4
Agricultural Research Service	588	547	524	506	479	463	470	451	7	4
Cooperative State Research Service	335	325	307	298	271	269	284	236	3	5
Forest Service	149	153	131	136	127	113	113	108	−3	6
EPA	442	417	380	347	348	317	320	261	6	8
Interior	489	504	469	417	404	385	392	411	−3	2
Geological Survey	305	300	278	236	227	219	215	209	2	6
Commerce	426	424	398	389	402	399	399	358	0	3
National Oceanic & Atmospheric Administration	268	277	269	263	286	275	270	244	−3	1
National Institute of Standards & Technology	145	133	116	108	99	101	101	96	9	6
Others	1,475	1,416	1,384	1,186	1,298	1,325	1,367	1,427	2	0
TOTAL	$66,107	$62,320	$61,406	$56,935	$55,255	$51,412	$48,332	$42,225	6%	7%
ANNUAL CHANGE	1%	6%	8%	3%	7%	6%	14%	9%		

Note: Fiscal years. a Estimated. **Source:** National Science Foundation

PERFORMERS OF FEDERALLY FUNDED R&D: **Industry's growing share tops 50% of total**

Federal obligations, $ millions	1991[a]	1990[a]	1989	1988	1987	1986	1985	1984	Annual change 1990-91[a]	Annual change 1984-91
Industry	$33,574	$30,908	$30,508	$28,630	$28,628	$25,898	$23,496	$20,219	9%	8%
FFRDCs[b] administered by industry	2,062	2,054	1,960	1,911	1,860	1,697	1,791	1,608	0	4
Federal intramural Programs	16,396	16,094	15,121	14,115	13,413	13,535	12,945	11,572	2	5
Universities and colleges	12,845	12,158	12,169	11,302	10,545	9,327	9,156	8,033	6	7
FFRDCs[b] administered by universities	3,654	3,410	3,497	3,474	3,210	2,768	2,816	2,486	7	6
Nonprofit institutions	2,784	2,629	2,521	2,188	2,221	2,228	2,388	2,094	6	4
FFRDCs[b] administered by nonprofit institutions	482	445	522	506	511	551	689	597	8	−4
Foreign	326	357	919	392	295	298	245	176	−9	9
State and local governments	184	175	167	142	148	128	129	131	5	5
TOTAL	$66,108	$62,321	$61,406	$56,769	$55,253	$51,412	$48,360	$42,225	6%	7%
ANNUAL CHANGE	6%	1%	8%	3%	7%	6%	15%	16%		

Note: Fiscal years. a Estimated. b Federally funded R&D centers. **Source:** National Science Foundation

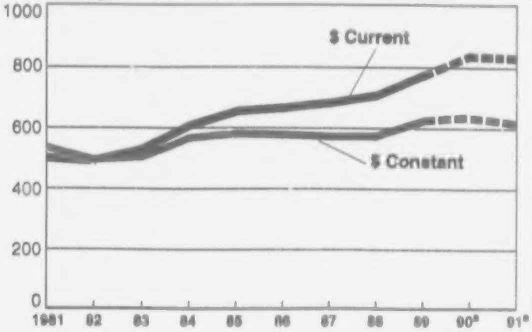
FEDERAL OBLIGATIONS FOR SCIENTIFIC DISCIPLINES: **Chemistry lags most other fields**

$ Millions for research only	1991[a]	1990[a]	1989	1988	1987	1986	1985	1984	Annual change 1990-91	Annual change 1989-91
Life sciences	$ 9,407	$ 8,914	$ 8,495	$ 7,724	$ 7,344	$ 6,464	$ 6,366	$ 5,836	6%	8%
Engineering	4,684	4,361	4,442	3,956	3,906	3,739	3,629	3,624	7	4
National engineering centers	790	814	784	678	669	632	664	858	−3	−1
Metallurgy and materials	599	520	521	457	362	445	439	341	15	8
Chemical	250	235	230	258	216	246	254	145	6	8
Physical sciences	4,191	3,894	3,705	3,317	3,253	3,069	3,044	2,969	8	5
Physics	2,479	2,287	2,191	1,975	1,854	1,806	1,820	1,836	8	4
Chemistry	832	839	782	703	680	662	645	606	−1	5
Environmental sciences	2,345	2,104	1,773	1,607	1,512	1,462	1,404	1,276	11	9
Mathematical and computer sciences	792	721	735	643	641	615	578	440	10	9
Other sciences	1,801	1,689	1,671	1,402	1,288	1,133	1,110	1,034	7	8
TOTAL	$23,220	$21,683	$20,765	$18,649	$17,943	$16,502	$16,130	$14,979	7%	6%
ANNUAL CHANGE	7%	4%	11%	4%	9%	2%	8%	5%		

Note: Fiscal years. a Estimated. **Source:** National Science Foundation

Real support for chemical research rose less than 2% per year over past decade

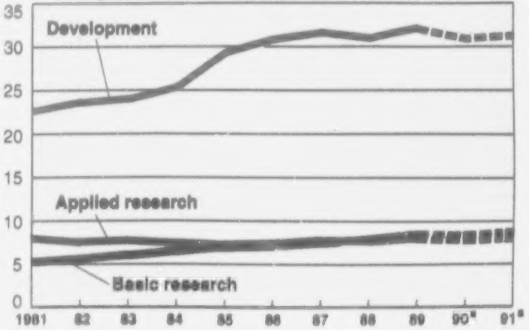
Federal obligations, $ millions



Note: Fiscal years. Constant-dollar (1982) values calculated by C&EN from NSF data. a Estimated. **Source:** National Science Foundation

Funding for basic research continues to climb, other areas have leveled off

Federal obligations for research, $ billions, constant (1982)



Note: Fiscal years. Constant-dollar values calculated by C&EN from NSF data. a Estimated. **Source:** National Science Foundation

FEDERAL OBLIGATIONS FOR BASIC RESEARCH: Growth averaging 8% per year

$ Millions	1991a	1990a	1989	1988	1987	1986	1985	1984	Annual change 1990–91	Annual change 1984–91
Health & Human Services	$ 4,940	$ 4,662	$ 4,388	$4081	$3830	$3339	$3233	$2815	6%	8%
National Institutes of Health	4,501	4,257	4,053	3795	3577	3119	3018	2625	6	8
Alcohol, Drug Abuse & Mental Health Administration	398	357	308	266	232	203	197	171	11	13
NSF	1,853	1,651	1,563	1433	1371	1275	1262	1132	6	7
NASA	1,803	1,659	1,417	1113	1014	917	751	755	9	13
Energy	1,677	1,531	1,411	1185	1069	960	943	830	9	11
Defense	972	892	948	877	908	924	861	848	9	2
Navy	399	354	354	342	354	337	343	316	13	3
Air Force	201	177	203	196	222	216	198	192	14	1
Army	191	177	187	166	217	248	241	222	8	−2
Defense agencies	181	184	204	173	115	122	79	118	−2	6
Agriculture	547	513	485	481	446	433	445	393	7	5
Agricultural Research Service	317	295	283	271	253	248	250	241	7	4
Cooperative State Research Service	163	150	143	146	133	132	142	100	9	7
Forest Service	56	58	50	52	49	42	44	41	−5	5
Interior	191	200	189	126	135	133	138	126	−4	6
Geological Survey	153	153	140	90	85	83	81	79	0	10
Bureau of Mines	32	43	44	32	46	45	50	41	−26	−4
EPA	98	76	51	27	31	39	39	30	30	18
Commerce	33	30	29	31	26	27	23	21	10	7
National Institute of Standards & Technology	32	29	28	26	25	26	22	20	10	7
Others	141	134	121	120	116	107	124	119	5	9
TOTAL	$12,255	$11,348	$10,602	$9474	$8944	$8153	$7819	$7067	8%	8%
ANNUAL CHANGE	8%	7%	12%	6%	10%	4%	11%	13%		

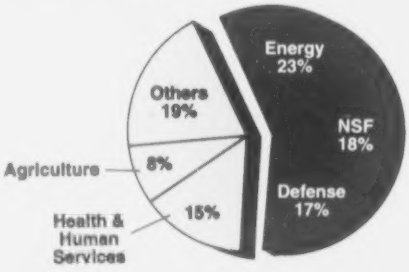
Note: Fiscal years. a Estimated. **Source:** National Science Foundation

FEDERAL OBLIGATIONS FOR APPLIED RESEARCH: Funds for NASA growing rapidly

$ Millions	1991a	1990a	1989	1988	1987	1986	1985	1984	Annual change 1990–91	Annual change 1984–91
Health & Human Services	$ 3,037	$ 2,915	$ 2,700	$2416	$2195	$1851	$1796	$ 1652	4%	9%
National Institutes of Health	2,179	2,117	2,008	1866	1740	1469	1410	1286	3	8
Alcohol, Drug Abuse & Mental Health Administration	516	459	385	287	241	192	180	165	12	18
Defense	2,497	2,343	2,708	2362	2440	2303	2307	2201	7	2
Defense agencies	849	846	1,038	791	751	735	738	717	0	2
Army	604	543	636	586	693	579	583	487	11	3
Air Force	580	529	605	577	563	542	538	548	10	1
Navy	464	425	429	406	432	447	448	450	9	0
NASA	1,970	1,636	1,461	1219	1256	1152	1033	955	20	11
Energy	1,064	1,109	1,021	1051	1029	1081	1198	1195	−4	−2
Agriculture	570	552	517	505	473	484	466	442	3	4
Agricultural Research Service	235	219	209	200	201	188	192	184	7	3
Cooperative State Research Service	172	175	165	153	138	137	143	136	−2	3
Forest Service	88	90	77	80	73	68	66	64	−2	5
Commerce	329	337	322	311	313	313	301	276	−2	3
National Oceanic & Atmospheric Administration	229	240	234	225	234	237	224	198	−5	3
National Institute of Standards & Technology	91	87	78	73	64	63	65	64	5	5
EPA	265	240	223	241	246	179	176	142	10	9
Interior	261	270	253	266	247	235	231	254	−3	0
Geological Survey	135	132	127	136	132	128	130	125	2	1
NSF	130	115	108	100	99	78	84	71	13	9
Others	842	818	840	705	700	693	720	725	3	2
TOTAL	$10,965	$10,335	$10,163	$9176	$8999	$8349	$8312	$ 7911	6%	5%
ANNUAL CHANGE	6%	2%	11%	2%	8%	0%	5%	−1%		

Note: Fiscal years. a Estimated. **Source:** National Science Foundation

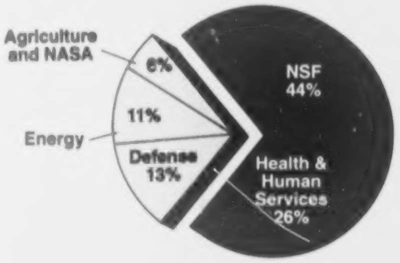
Three agencies provide nearly 60% of all chemical research funding . . .



Estimated fiscal 1991 federal chemistry research obligations = $832 million

Source: National Science Foundation

. . . but NSF and HHS alone provide 70% of the funds for universities



Estimated fiscal 1991 federal chemistry university research obligations = $315 million[a]

a Total is for these six agencies only.

UNIVERSITY RESEARCH: Life sciences garner just under 60% of government funds

Federal obligations, $ millions	1991[a]	1990[a]	1989	1988	1987	1986	1985	1984	Annual change 1990–91	Annual change 1984–91
Life sciences	$4682	$4428	$4396	$4029	$3824	$3252	$3192	$2800	6%	8%
Physical sciences	1035	960	930	857	823	752	750	698	8	6
Physics	546	504	486	425	404	405	402	375	8	6
Chemistry	315	298	298	295	281	266	267	242	6	5
Engineering	806	721	749	673	600	609	507	474	12	8
Metallurgy and materials	213	171	194	175	108	133	107	88	25	13
Chemical	48	43	42	57	55	51	46	51	12	−1
Environmental sciences	511	475	460	408	400	366	361	320	8	7
Mathematical and computer sciences	359	354	344	305	289	274	253	182	1	10
Other sciences	640	609	593	494	449	365	348	304	5	11
TOTAL	$8033	$7547	$7472	$6766	$6384	$5617	$5411	$4777	6%	8%
ANNUAL CHANGE	6%	1%	10%	6%	14%	4%	13%	12%		

Note: Fiscal years. Includes funding only from six agencies that together represent approximately 96% of federal research support to universities. a Estimated.
Source: National Science Foundation

UNIVERSITY RESEARCH IN CHEMISTRY: NSF, NIH, and DOD dominate funding

Federal obligations, $ millions	1991[a]	1990[a]	1989	1988	1987	1986	1985	1984	Annual change 1990–91	Annual change 1984–91
NSF	$139.7	$124.5	$118.5	$111.6	$107.1	$103.5	$108.1	$100.7	12%	5%
Health & Human Services	80.5	76.6	76.4	91.4	85.0	75.0	75.2	63.2	5	4
National Institutes of Health	78.1	74.6	74.8	89.3	83.4	74.4	74.7	62.8	5	3
Alcohol, Drug Abuse & Mental Health Administration	2.4	2.0	1.6	2.1	1.6	0.6	0.6	0.4	20	29
Defense	42.1	39.2	42.0	41.3	45.0	43.2	40.4	34.7	7	3
Air Force	16.8	14.9	15.5	17.0	18.4	16.1	14.0	na	13	na
Navy	15.7	14.8	14.3	13.6	17.2	13.9	15.5	na	6	na
Army	6.7	6.7	7.7	8.8	8.3	12.4	10.9	na	0	na
Defense agencies	2.8	2.8	4.4	1.8	1.1	0.9	0	na	0	na
Energy	35.4	39.8	43.7	33.8	28.5	27.6	26.0	26.3	−11	15
Agriculture	11.1	12.1	11.8	11.8	11.2	12.2	15.5	13.5	−8	−3
NASA	6.4	5.9	5.2	4.8	4.3	4.2	4.1	4.1	8	7
TOTAL	$315.2	$298.1	$297.7	$294.7	$281.1	$265.7	$269.4	$242.3	6%	4%
ANNUAL CHANGE	6%	0%	1%	5%	6%	−1%	11%	18%		

Note: Fiscal years. Data from these six agencies represent approximately 96% of federal obligations for 1991. a Estimated. na = not available. **Source:** National Science Foundation

FEDERAL OBLIGATIONS FOR DEVELOPMENT: Defense Department accounts for 78%

$ Millions	1991ᵃ	1990ᵃ	1989	1988	1987	1986	1985	1984	Annual change 1990–91	Annual change 1984–91
Defense	$33,448	$32,644	$33,921	$32,176	$31,884	$29,711	$26,623	$22,324	2%	6%
Air Force	12,801	13,013	14,430	14,261	14,563	12,835	12,524	11,352	−2	2
Navy	8,494	8,810	8,883	8,766	8,721	8,866	8,336	6,840	−4	3
Defense agencies	6,319	5,713	5,617	4,868	4,354	3,911	1,965	557	11	41
Army	5,433	4,873	4,836	4,052	4,110	3,982	3,747	3,517	11	6
NASA	4,549	3,340	2,515	1,999	1,518	1,351	1,544	1,113	36	22
Energy	3,265	3,057	2,761	2,801	2,659	2,648	2,825	2,649	7	3
Health & Human Services	911	881	814	661	584	468	423	365	3	15
National Institutes of Health	793	725	682	610	536	418	400	347	3	14
Transportation	261	249	182	213	256	317	358	371	5	−4
EPA	80	101	107	80	71	100	106	89	−20	−2
Commerce	64	56	47	47	64	60	75	62	14	0
National Oceanic & Atmospheric Administration	39	37	34	35	52	37	45	47	1	−2
National Institute of Standards & Technology	22	17	10	9	9	12	14	12	29	9
Agriculture	41	38	36	31	29	32	32	31	8	4
Agricultural Research Service	35	32	31	26	24	27	28	27	9	4
Interior	37	34	26	24	22	17	22	31	9	3
Geological Survey	18	15	13	11	10	7	4	5	20	29
Others	232	237	230	253	226	207	195	212	−2	1
TOTAL	$42,888	$40,637	$40,640	$38,285	$37,313	$34,910	$32,202	$27,246	6%	7%
ANNUAL CHANGE	6%	0%	6%	3%	7%	8%	18%	11%		

Note: Fiscal years. a Estimated. **Source:** National Science Foundation

ENGINEERING RESEARCH: Over past five years support for chemical engineering has fallen by an

Federal obligations, $ millions	1991ᵃ All engineering	1991ᵃ Chemical engineering	1991ᵃ Metallurgy & materials	1990ᵃ All engineering	1990ᵃ Chemical engineering	1990ᵃ Metallurgy & materials	1989 All engineering	1989 Chemical engineering	1989 Metallurgy & materials
Defense	$1747.7	$40.9	$396.0	$1619.1	$ 41.6	$328.3	$1836.1	$ 46.8	$343.3
Air Force	463.2	3.3	47.4	409.4	3.3	44.7	480.5	11.6	42.9
Defense agencies	452.2	0	259.3	443.9	0	204.7	565.1	0.2	221.6
Navy	432.6	14.6	61.2	390.2	12.4	55.4	389.9	11.6	56.1
Army	399.7	23.0	28.1	375.6	25.9	23.5	400.6	23.4	22.7
NASA	1669.1	12.3	50.2	1513.2	13.5	40.7	1446.4	6.0	35.5
Energy	420.0	3.0	78.4	436.2	5.5	79.8	406.1	4.5	78.0
NSF	276.4	50.6	33.4	245.7	44.9	29.7	232.0	42.4	28.1
Transportation	93.3	6.9	0.3	89.5	6.3	0.3	87.6	6.9	0.2
Interior	76.8	6.6	26.8	94.2	5.7	28.1	92.8	5.8	23.4
EPA	71.4	28.9	0.6	62.2	23.7	0.6	52.7	19.2	0.7
Commerce	60.8	5.4	13.3	60.5	3.8	12.3	52.7	3.2	11.6
Agriculture	34.2	7.7	0	36.7	7.5	0	34.5	7.2	0
Others	214.2	0	0.1	203.8	0.1	0	201.1	0.2	0.2
TOTAL	$4663.9	$162.1	$599.1	$4361.1	$152.6	$519.8	$4442.0	$142.2	$521.0
ANNUAL CHANGE	7%	6%	15%	−2%	7%	0	12%	−45%	14%

Note: Fiscal years. a Estimated. **Source:** National Science Foundation

FEDERAL OBLIGATIONS FOR CHEMICAL RESEARCH: **NSF now second largest source of funds**

$ Millions	1991[a]	1990[a]	1989	1988	1987	1986	1985	1984	Annual change 1990-91	Annual change 1984-91
Energy	$190.4	$238.4	$213.4	$162.9	$145.5	$145.9	$143.0	$140.4	−20%	4%
NSF	151.2	134.6	127.4	120.6	115.3	112.6	115.6	109.9	12	5
Defense	141.2	131.0	133.5	125.0	144.9	163.4	156.4	139.6	8	0
Army	65.3	64.0	60.4	57.5	72.2	81.4	78.2	66.3	2	−1
Air Force	43.9	38.1	43.2	43.6	43.3	42.0	39.5	36.7	15	3
Navy	29.2	26.1	25.5	22.1	28.4	39.1	38.3	36.6	12	−4
Defense agencies	2.8	2.8	4.4	1.8	1.1	0.9	0.4	0.3	0	38
Health & Human Services	122.7	114.8	107.8	123.8	115.5	104.2	99.1	86.3	7	5
National Institutes of Health	108.9	103.6	98.6	114.4	108.1	99.5	95.1	84.1	5	4
Alcohol, Drug Abuse & Mental Health Administration	13.8	11.2	9.2	9.4	7.4	4.7	4.0	2.3	23	29
Agriculture	64.8	62.9	[illegible]1.0	60.8	65.0	58.6	58.0	69.0	3	−1
Agricultural Research Service	44.8	41.7	41.2	40.9	46.4	40.0	36.1	51.6	7	−2
Cooperative State Research Service	11.5	12.5	12.3	12.2	11.5	12.4	16.1	13.5	−8	−3
Forest Service	8.5	8.7	7.5	7.6	7.1	6.2	5.7	3.9	−2	12
NASA	52.2	57.9	47.4	27.5	13.4	11.8	16.3	7.3	−10	32
EPA	46.4	37.4	32.5	30.6	34.6	20.1	17.5	15.9	24	16
Commerce	25.5	25.1	24.4	23.6	22.9	19.1	17.7	15.3	2	9
National Institute of Standards & Technology	20.2	18.3	17.7	16.9	16.5	16.4	15.4	14.1	10	5
National Oceanic & Atmospheric Administration	5.3	6.8	6.7	6.7	6.4	2.4	1.4	1.3	−12	26
Interior	25.1	22.7	22.0	21.9	20.9	20.3	19.4	19.2	11	4
Geological Survey	25.0	22.6	21.9	20.8	20.2	19.4	18.4	11	4	
Others	12.9	14.2	13.2	6.4	2.4	6.3	1.5	3.3	−9	22
TOTAL	$832.4	$839.0	$782.6	$703.1	$680.3	$662.4	$644.5	$606.4	1%	5%
ANNUAL CHANGE	−1%	7%	11%	3%	3%	3%	6%	17%		

Note: Fiscal years. a Estimated. **Source:** National Science Foundation

average of 8% a year

1988			1987			1986		
All engineering	Chemical engineering	Metallurgy & materials	All engineering	Chemical engineering	Metallurgy & materials	All engineering	Chemical engineering	Metallurgy & materials
$1636.1	$ 41.9	$294.4	$1629.7	$ 46.[illegible]	$203.6	$1505.6	$ 50.3	$253.7
455.1	1.8	43.2	460.3	1.8	34.5	444.7	1.9	33.4
416.8	0.1	174.8	325.6	0	79.8	269.5	0	76.2
379.6	19.6	52.5	401.5	21.3	57.2	397.8	24.4	117.4
384.4	20.3	23.6	442.4	23.8	32.1	373.6	24.0	26.8
1138.2	2.0	18.6	1170.5	1.5	19.9	1066.9	1.0	16.2
479.5	134.5	78.4	442.2	88.9	77.1	494.2	121.6	62.8
206.6	38.9	25.6	191.7	37.3	22.9	199.1	33.4	43.5
71.9	1.0	3.6	48.1	1.0	0.7	52.8	1.9	1.8
85.3	6.1	24.8	87.8	5.0	28.5	93.2	4.7	38.5
50.7	24.2	0.3	55.4	25.6	0.5	46.6	23.9	0.6
49.3	2.7	10.6	41.3	2.4	5.6	41.7	2.6	7.6
31.7	7.7	0	33.9	6.9	0	31.1	6.0	0
206.7	0.1	0.2	205.8	0.3	0.2	205.9	0.4	0.6
$3956.2	$258.1	$456.7	$3906.2	$215.8	$362.0	$3738.9	$245.8	$445.0
1%	20%	26%	4%	−12%	−19%	3%	−3%	1%

Fiscal 1992 is shaping up well for R&D, as Congress slates budget increases for funding agencies

DOD R&D BUDGET: Air Force work accounts for just under 40%

	1992					
$ Millions	House appropriation	Administration request	1991	1990	1989	% change 1991-92[a]
Air Force	$14,263.9	$15,032.6	$11,961.3	$14,626.9	$14,502[illegible]	19%
Defense agencies	8,979.1	10,238.5	9,115.7	8,399.4	8,427.9	−1
Navy	7,464.9	7,346.6	9,237.9	9,393.6	9,382.3	−20
Army	6,241.6	6,307.3	5,607.4	5,446.5	5,130.2	1
TOTAL	**$36,949.5**	**$38,921.0**	**$35,722.3**	**$37,866.4**	**$37,442.7**	3%

Note: Fiscal years. a Based on House appropriation.

DEPARTMENT OF ENERGY: Defense accounts for just 30% of R&D budget

	1992					
$ Millions	Congressional appropriation	Administration request	1991	1990	1989	% change 1991-92
ENERGY R&D	**$4236.1**	**$4031.2**	**$3717.3**	**$3053.3**	**$2927.4**	**14%**
General science and research	**1472.5**	**1548.9**	**1148.7**	**737.6**	**717.6**	**28**
Basic energy sciences	**764.7**	**714.7**	**711.7**	**582.5**	**552.4**	**7**
Materials sciences	257.1	257.1	274.9	203.2	180.7	−6
Chemical sciences	158.3	158.3	157.6	144.1	135.0	0
Fossil	**450.0[a]**	**227.0**	**458.8**	**416.5**	**380.6**	**−2[b]**
Environment	**353.3**	**312.6**	**393.9**	**314.0**	**259.0**	**−10**
Fusion	**337.1**	**337.1**	**273.6**	**323.0**	**351.5**	**23**
Nuclear	**332.0**	**398.0**	**304.0**	**348.0**	**352.7**	**9**
Conservation	**284.8[a]**	**290.9**	**228.3**	**191.2**	**165.7**	**25**
Solar, other renewables	**241.7**	**202.1**	**198.3**	**140.5**	**147.9**	**22[b]**
DEFENSE R&D	**1926.2**	**1752.2**	**1729.8**	**1704.4**	**1608.9**	**11**
Weapons R&D	1231.0	1074.0	1077.8	1022.2	978.9	14
Naval reactor development	695.2	678.2	652.0	642.2	630.0	7
TOTAL	**$6162.3**	**$5783.4**	**$5447.1**	**$4757.7**	**$4536.3**	**13%**

Note: Fiscal years. a C&EN estimate based on Congressional action as of Aug. 2, 1991. b Based on estimated appropriation.

NIH BUDGET: Cancer, aging, genome research slated for largest increases

	1992					
$ Millions	Congressional appropriation[a]	Administration request	1991	1990	1989	Annual change 1991-92[b]
National Institutes	**$8065.9**	**$7982.0**	**$7438.9**	**$6893.8**	**$6561.9**	**8%**
Cancer	1920.3	1810.2	1713.8	1634.3	1570.9	12
Heart, Lung & Blood	1196.5	1209.9	1126.9	1072.3	1045.7	6
Allergy & Infectious Diseases	966.4	976.7	907.3	833.0	742.3	6
General Medical Sciences	817.7	833.2	760.0	712.0	682.2	8
Diabetes & Digestive & Kidney Diseases	660.3	658.6	615.3	581.5	559.6	7
Neurological Disorders & Stroke	583.4	583.4	541.7	490.4	472.3	8
Child Health & Human Development	524.2	520.6	479.0	442.9	425.5	9
Aging	362.8	348.6	323.7	239.5	222.8	12
Eye	269.7	272.3	253.2	236.5	231.3	6
Environmental Health Sciences	252.9	254.5	241.0	229.2	223.7	5
Arthritis & Musculoskeletal & Skin Diseases	204.0	204.8	193.2	168.9	160.0	6
Dental Research	159.7	160.9	148.9	135.7	130.8	7
Deafness & Other Communication Disorders	148.0	148.3	134.9	117.6	94.8	10
National Center for Research Resources	**313.2**	**321.0**	**335.3**	**337.1**	**358.3**	**−7**
National Center for Human Genome Research	**101.2**	**110.5**	**87.4**	**59.5**	**28.0[c]**	**16**
Other	**411.6**	**361.4**	**415.1**	**285.9**	**224.6**	**−1**
TOTAL	**$8891.9**	**$8774.9**	**$8276.7**	**$7576.3**	**$7144.8**	**7%**

Note: Fiscal years. a C&EN estimate based on Congressional action as of Aug. 2, 1991. b Based on estimated appropriation. c Funded under National Institute for General Medical Sciences.

AGRICULTURE R&D: Budget will be up, contrary to funding request

	1992					
$ Millions	**Congressional appropriation[a]**	**Administration request**	**1991**	**1990**	**1989**	**% change 1991-92[b]**
Agricultural Research Service	$ 701.9	$ 709.2	$ 665.1	$ 596.8	$ 591.7	6%
Cooperative State Research Service	478.0	409.2	451.4	382.8	315.1	6
Forest Service	180.2	163.2	167.6	147.1	137.9	8
National Agricultural Library	17.2	17.5	16.8	14.7	14.3	2
TOTAL	**$1377.3**	**$1299.1**	**$1300.9**	**$1150.4**	**$1064.4**	6%

Note: Fiscal years. **a** C&EN estimate based on Congressional action as of Aug. 2, 1991. **b** Based on estimated appropriation.

NSF BUDGET: Big increase for education, academic instrumentation funding debuts

	1992					
$ Millions	**Congressional appropriation[a]**	**Administration request**	**1991**	**1990**	**1989**	**% change 1991-92[b]**
Research and related activities	$1943.2	$1963.5	$1694.2	$1702.4	$1620.5	15%
Education and human resource activities	450.0	390.0	322.4	204.3	171.0	40%
Salaries and expenses	113.0	122.0	101.0	96.4	89.8	12
Antarctic research	98.0	118.0	100.0	71.9	131.0	−2
Academic research facilities	20.0	0	20.5	19.7	0	−2
Academic research instrumentation[c]	50.0	50.0	0	0	0	—
TOTAL	**$2644.2**	**$2643.5**	**$2238.1**	**$2094.7**	**$2012.3**	18%

Note: Fiscal years. **a** C&EN estimate based on Congressional action as of Aug. 2, 1991. **b** Based on estimated appropriation **c** New program proposed by Administration for fiscal 1992.

NASA R&D BUDGET: Space station funding eating into other programs

	1992					
$ Millions	**Congressional appropriation[a]**	**Administration request**	**1991**	**1990**	**1989**	**% change 1991-92[b]**
Space station and applications	$2648.9	$2909.2	$2518.1	$2007.0	$1855.9	5%
Space station	2022.5	2022.5	1894.5	1714.9	877.3	7
Space transportation capability development	650.0	865.9	658.9	637.3	707.0	−1
Aeronautical research & technology	535.4	582.2	511.5	449.3	395.7	5
Space research & technology	354.3	415.3	305.2	285.2	297.2	16
Commercial programs	99.8	146.8	89.9	58.3	53.1	11
Academic programs	65.9	64.1	61.7	28.2	—	7
Transatmospheric vehicle	48.2	73.2	92.4	59.1	71.2	−48
Safety, reliability & quality assurance	33.6	33.6	35.3	21.9	21.2	−5
Tracking & data systems	21.9	21.9	19.5	19.8	19.3	12
TOTAL	**$6480.5**	**$7134.7**	**$6094.6**	**$5291.9**	**$4297.9**	5%

Note: Fiscal years. **a** C&EN estimate based on Congressional action as of August 2, 1991. **b** Based on estimated appropriation.

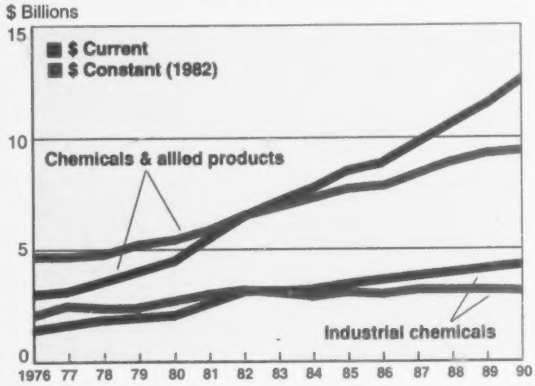
EPA R&D BUDGET: Big boosts for air and pesticides research, only Superfund research declines

	1992					
$ Millions	**Congressional appropriation[a]**	**Administration request**	**1991**	**1990**	**1989**	**% change 1991-92[b]**
Multimedia	$153.6	$150.7	$124.2	$ 84.0	$ 44.3	24%
Air	119.2	112.4	86.6	77.9	67.7	38
Superfund	68.6	68.6	73.6	78.7	73.4	−7
Hazardous waste	46.7	43.6	39.2	43.9	43.5	19
Water quality	31.1	28.9	27.7	26.9	24.1	7
Toxic substances	26.3	26.3	25.5	27.2	27.9	3
Drinking water	23.7	22.2	20.7	20.9	21.3	14
Pesticides	19.3	15.0	12.6	12.7	13.3	53
Energy/acid rain	15.8	13.7	13.6	33.3	54.5	16
Management & support	5.3	5.3	5.2	14.7	12.6	2
Radiation	5.1	4.0	4.0	3.6	3.5	27
Leaking underground storage tanks	0.8	0.8	0.8	0.7	0.8	0
TOTAL	**$515.5**	**$491.5**	**$433.7**	**$424.5**	**$386.9**	19%

Note: Fiscal years. **a** C&EN estimates based on Congressional action as of Aug. 2, 1991. **b** Based on estimated appropriation.

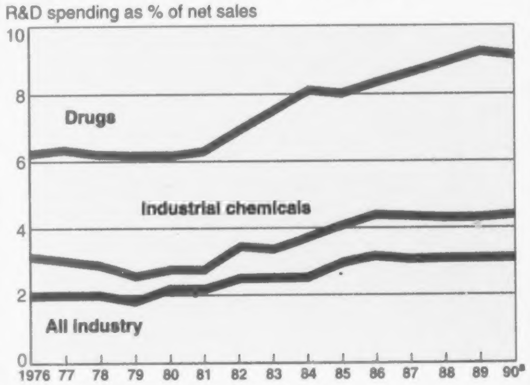
Chemicals R&D Outpaces Other Industries

In constant dollars, R&D spending for all chemicals rose modestly last year



Note: Constant-dollar values calculated by C&EN from NSF data.
Source: National Science Foundation

Share of revenues for R&D is higher at drug firms than in other industries



a C&EN estimates. **Source:** National Science Foundation

TOTAL FUNDS FOR INDUSTRIAL R&D: Overall support increased only 3% in 1990

$ Millions	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	Annual change 1989–90	Annual change 1980–90
Chemicals and allied products	$ 12,700[a]	$ 11,537	$10,774	$ 9,878	$ 8,843	$ 8,540	$ 7,927	$ 7,185	$ 6,604	$ 5,625	$ 4,636	10%	11%
Industrial chemicals	4,300[a]	4,056	3,959	3,901	3,552	3,498	3,240	3,214	3,206	2,802	2,197	6	7
Drugs	6,100[a]	5,400[a]	4,737	4,108[a]	3,658	3,490[a]	3,316[a]	2,901[a]	2,481[a]	2,073[a]	1,777	13	14
Other chemicals	2,300[a]	2,081[a]	2,078	1,869[a]	1,633	1,552[a]	1,371[a]	1,070[a]	917[a]	750[a]	662	11	13
Other industries	91,500[a]	90,062	87,115	82,277	78,980	75,699	66,873	$58,083	52,046	46,185	39,869	2	9
TOTAL	$104,200	$101,599	$97,889	$92,155	$87,823	$84,239	$74,800	$65,268	$58,650	$51,810	$44,505	3%	9%

a C&EN estimates. **Source:** National Science Foundation

COMPANY FUNDS FOR INDUSTRIAL R&D: Outlays for drug R&D grew fastest in 1989

$ Millions	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	Annual change 1988–89	Annual change 1979–89
Chemicals and allied products	$11,449	$10,580	$ 9,685	$ 8,664	$ 8,310	$ 7,736	$ 6,792	$ 6,197	$ 5,205	$ 4,264	$ 3,692	8%	12%
Industrial chemicals	3,972	3,767	3,714	3,374	3,281	3,057	2,828	2,810	2,393	1,856	1,617	5	9
Drugs	5,206	4,735	4,139	3,657	3,481	3,310	2,896	2,473	2,064	1,756	1,516[a]	10	13
Other chemicals	2,271	2,078	1,832	1,633	1,548	1,369	1,068	914	747	653	559[a]	9	15
Other industries	58,804	55,883	53,121	51,268	48,733	43,668	37,796	33,908	30,223	26,212	22,016	5	10
TOTAL	$70,253	$66,463	$62,806	$59,932	$57,043	$51,404	$44,588	$40,105	$35,428	$30,476	$25,708	6%	11%

a C&EN estimates. **Source:** National Science Foundation

FEDERAL FUNDS FOR INDUSTRIAL R&D: Funds for chemical industry cut in half

												Annual change	
$ Millions	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1988–89	1979–89
Chemicals and allied products	$ 88	$ 195	$ 192	$ 179	$ 230	$ 191[a]	$ 393	$ 407	$ 421	$ 372	$ 346	−55%	−13%[a]
Industrial chemicals	84	192	187	178	217	183[a]	386	396	409	341	345	−56	−13[a]
Drugs and other chemicals	4	3	5	1	13	8	7	11	12	31	1	33	15
Other industries	31,278	32,764	31,119	27,712	26,966	23,205	20,287	18,138	15,961	13,657	12,172	−5	10
TOTAL	$31,366	$32,959	$31,311	$27,891	$27,196	$23,396	$20,680	$18,545	$16,382	$14,029	$12,518	−5%	10%

a The decline in 1984 from 1983 results from the administration of federally funded Oak Ridge National Laboratory being changed from a chemical company to a company in the aircraft and missile industry. **Source:** National Science Foundation

COST PER INDUSTRIAL R&D SCIENTIST OR ENGINEER: 5% increase for chemicals in 1989

$ Thousands	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979
Chemicals and allied products	$147.9	$140.4	$127.6	$117.1	$116.3	$112.5	$104.8	$102.5	$ 96.6	$ 87.4	$79.6
Industrial chemicals	176.0	173.6	165.5	150.2	144.5	132.0	123.1	122.1	118.0	103.4	92.8
Drugs	a	141.7	a	113.6	a	a	103.1	a	a	79.2	71.4
Other chemicals	a	101.3	a	83.1	a	a	a	a	a	66.5	66.5
All industry	$140.0	$137.0	$131.2	$128.4	$130.2	$124.0	$116.0	$111.6	$103.9	$ 94.9	$87.4

a Not separately available but included in chemicals and allied products. **Source:** Calculated by C&EN from National Science Foundation data

R&D BY U.S. COMPANIES ABROAD: Funds spent by chemical firms declined sharply in 1989

												Annual change	
$ Millions	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1988–89	1979–89
Chemicals and allied products	$1287	$1501	$1243	$1071	$ 843	$ 786	$ 729	$ 682	$ 715	$ 603	$ 500	−14%	10%
Industrial and other chemicals	473	781	625	579	444	385	368	319	287	246	199	−39	9
Drugs	814	720	618	492	399	401	361	363	428	357	301	13	10
Other industries	5232	4794	3983	3553	2807	2847	2540	2412	2678	2562	2254	9	9
TOTAL	$6519	$6295	$5226	$4624	$3650	$3633	$3269	$3094	$3393	$3165	$2754	4%	9%

Source: National Science Foundation

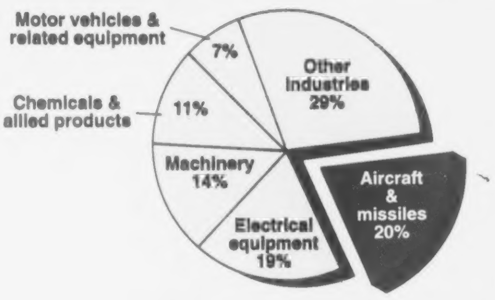
CHEMICAL R&D SPENDING: Company outlays rose 10% in 1990

$ Millions	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1990 R&D spending as % of sales
Du Pont	$1428	$1387	$1319	$1223	$1156	$1144	$1097	$ 966	$ 879	$ 718	$ 591	3.6%
Dow Chemical	1136	873	772	670	605	547	507	492	460	404	314	5.7
Monsanto	612	598	648	615	596	470	370	290	264	233	208	7.7
American Cyanamid	460	406	365	314	278	251	232	208	185	166	148	10.1
Union Carbide[a]	191	181	159	159	148	275	265	245	240	207	166	2.5
Rohm & Haas	178	175	156	142	133	124	109	100	92	77	67	6.3
W. R. Grace	148	125	119	107	94	92	81	73	64	57	45	2.2
Hercules	92	79	74	74	71	76	72	74	74	65	57	2.9
Lubrizol	74	70	65	62	51	44	33	37	36	33	28	5.2
Air Products	72	71	72	57	61	51	44	40	37	32	30	2.5
Olin	66	66	58	62	56	53	52	49	45	38	31	2.5
Ethyl	65[b]	61[b]	59[b]	50	47	47	40	39	39	37	34	2.6
International Flavors	57	52	50	45	39	34	32	32	31	30	29	6.0
Nalco Chemical	45	41	37	35	33	32	32	30	33	30	28	3.7
TOTAL	$4624	$4185	$3953	$3615	$3368	$3240	$2966	$2675	$2479	$2127	$1776	4.5%
ANNUAL CHANGE	10%	6%	9%	7%	4%	9%	11%	8%	17%	20%	16%	

Note: Prior years not restated to reflect company revisions. **a** Union Carbide divested a substantial part of its business in 1986; on a pro forma basis, R&D spending was $181 million in 1985 and $178 million in 1984. **b** Adjusted to reflect spin-off of Tredegar Industries. **Source:** Company data

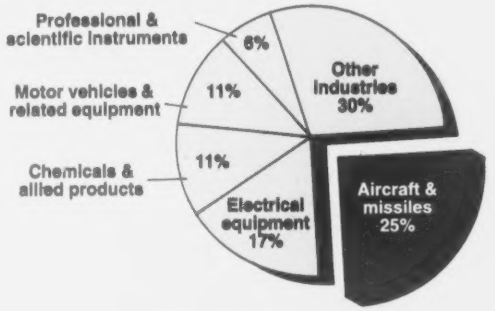
3 R&D Industry

Aircraft and missile firms employ one fifth of R&D scientists and engineers in industry . . .



1989 total industrial R&D scientists and engineers[a] = 726,000

. . . and spend one quarter of total industrial R&D funds in the U.S.



1989 total industrial R&D expenditures = $102 million

[a] Average full-time equivalent for 1989. **Source:** National Science Foundation

R&D SCIENTISTS AND ENGINEERS IN INDUSTRY: Drug firms show decline

Thousands	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	Annual change 1989–90	Annual change 1980–90
Chemicals and allied products	**78.4**	**77.6**	**75.8**	**75.2**	**75.8**	**71.1**	**69.8**	**67.3**	**61.6**	**54.7**	**51.4**	1%	4%
Industrial chemicals	23.0[a]	23.1[a]	22.5[a]	22.4[a]	24.9	23.5	25.6	26.6	25.9	21.6	20.9	0	2
Drugs	33.0	34.0	33.0	32.6	31.8	30.8	30.8[a]	28.2	25.6	23.3	21.6	−3	4
Other chemicals	22.4	20.5	20.3	20.2	19.1	16.7	13.4	12.1	10.1	9.8	8.9	9	10
Other industries	**653.3**	**642.6**	**632.8**	**620.6**	**595.2**	**551.4**	**514.3**	**473.6**	**448.2**	**433.1**	**399.2**	2	5
TOTAL	**731.7**	**720.2**	**708.6**	**695.8**	**671.0**	**622.5**	**584.1**	**540.9**	**509.8**	**487.8**	**450.6**	2%	5%

Note: Data as of January of each year for full-time equivalent personnel. a C&EN estimates. **Source:** National Science Foundation

CHEMISTS IN INDUSTRY: 15% work outside the manufacturing sector

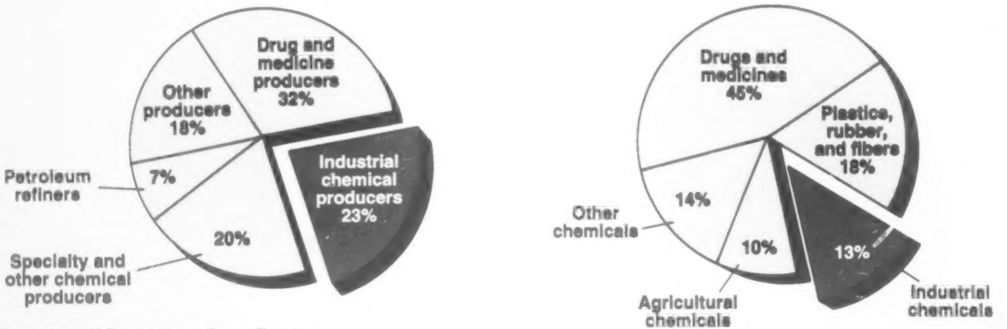
Industry	% of industrial chemists: All chemists	B.S.	M.S.	Ph.D.	Mean salary ($ thousands)[a]: B.S.	M.S.	Ph.D.
Manufacturing							
Pharmaceuticals[b]	18%	15%	21%	19%	$46.2	$56.4	$75.3
Specialty chemicals	14	13	11	15	48.7	57.0	67.6
Basic chemicals	6	3	4	8	51.5	68.4	71.7
Plastics	5	3	5	6	51.8	61.6	68.4
Coatings	4	5	3	3	49.7	59.2	62.2
Petroleum and natural gas	4	4	3	5	53.5	65.1	76.2
Medical devices	4	3	3	4	47.2	56.2	71.2
Agricultural chemicals	3	2	2	4	46.3	58.6	67.1
Electronics	3	3	3	3	46.4	58.5	76.2
Food	3	3	4	2	46.4	58.0	72.9
Aerospace	3	3	3	2	51.4	57.5	65.7
Instruments	2	3	3	2	53.0	58.0	66.1
Rubber	2	3	2	1	47.8	51.5	68.5
Biochemical products	1	1	1	2	46.5	61.3	63.2
Metals and minerals	1	2	2	1	38.7	52.0	52.1
Soaps and detergents	1	1	1	2	47.3	49.3	69.8
Paper	1	1	1	1	42.6	55.5	64.5
Other	11	11	11	10	45.8	58.9	68.3
Nonmanufacturing							
Analytical service labs	6	11	6	2	41.1	44.4	64.7
Contract research firms	3	2	3	4	40.9	54.4	58.7
Other	6	8	8	4	51.4	55.7	68.9

[a] As of March 1, 1991; to facilitate comparison, mean salaries are adjusted for differences in average length of experience. [b] Includes personal care products. **Source:** ACS survey

Industrial chemical producers perform almost one quarter of chemical R&D . . .

. . . but industrial chemicals research takes only 13% of such R&D funds

1989 chemical R&D spending[a] = $5.9 billion



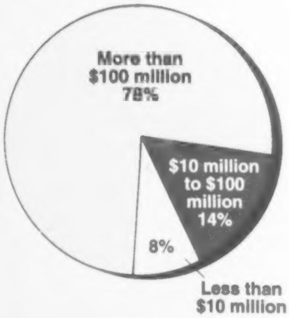
a Excludes basic research. **Source:** National Science Foundation

R&D SCIENTISTS AND ENGINEERS PER 1000 EMPLOYEES: **Drug firms lead with 101**

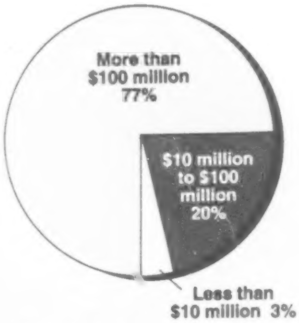
	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979
Chemicals and allied products	**72**	**70**	**68**	**70**	**57**	**57**	**54**	**51**	**44**	**42**	**42**
Industrial chemicals	55	55	52	56	39	41	45	44	37	36	36
Drugs	101	99	98	98	81	89	82	74	66	60	62
Other chemicals	65	61	61	63	62	51	39	37	33	30	27
All industry	**49**	**47**	**45**	**45**	**43**	**40**	**34**	**33**	**29**	**27**	**27**

Source: National Science Foundation

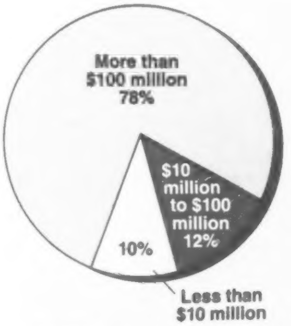
Chemical firms with research budgets under $10 million do their fair share of R&D



1989 chemicals and allied products R&D funds = $11.5 billion



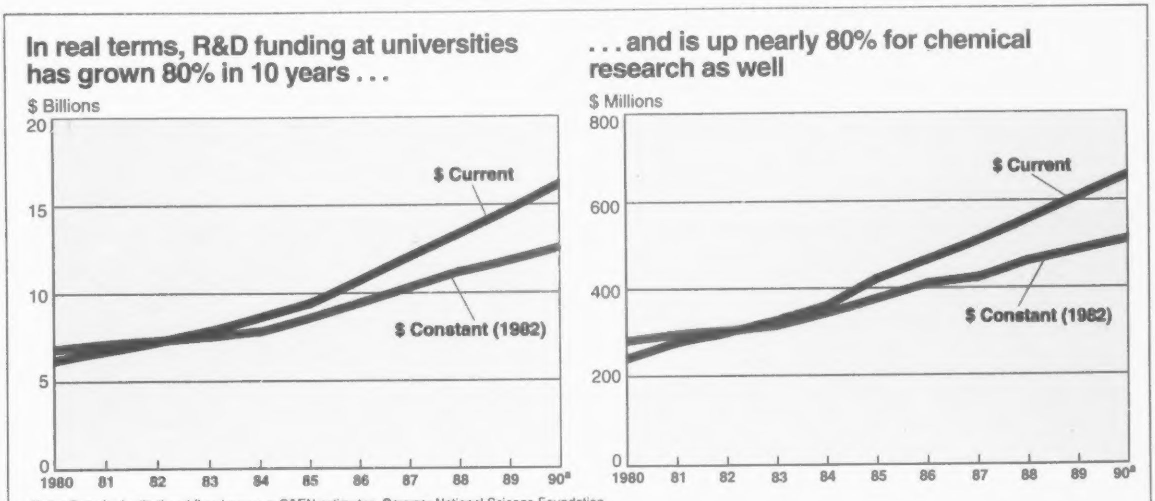
1989 industrial chemicals R&D funds = $4.1 billion



1989 Industry R&D funds=$102 billion

Note: Ranges indicate size of companies' 1989 R&D program. **Source:** National Science Foundation

Universities' R&D Outlays Near $15 Billion


In real terms, R&D funding at universities has grown 80% in 10 years . . .

. . . and is up nearly 80% for chemical research as well

Note: Data for institutional fiscal years. a C&EN estimates. **Source:** National Science Foundation

CHARACTER OF UNIVERSITY R&D SPENDING: In 1989, 35% of total was for applied R&D

												Annual change	
$ Millions	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1988–89	1979–89
Basic research	$ 9,685	$ 8,827	$ 8,398	$ 7,495	$6559	$5735	$5304	$4882	$4596	$4041	$3628	10%	10%
Applied research and development	5,303	4,638	3,755	3,431	3128	2882	2573	2441	2250	2035	1752	14	12
TOTAL	**$14,987**	**$13,465**	**$12,153**	**$10,926**	**$9686**	**$8617**	**$7877**	**$7323**	**$6846**	**$6077**	**$5380**	11%	11%
ANNUAL CHANGE	11%	11%	11%	13%	12%	9%	8%	7%	13%	13%	16%		

Note: Data for institutional fiscal years. **Source:** National Science Foundation

SOURCE OF UNIVERSITY R&D FUNDS: Institutional contribution up 14% in 1989

												Annual change	
$ Millions	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1988–89	1979–89
Federal government	$ 8,972	$ 8,181	$ 7,333	$ 6,702	$6056	$5423	$4983	$4763	$4565	$4104	$3604	10%	10%
Institutional funds	2,710	2,367	2,176	1,873	1622	1413	1303	1115	1008	837	738	14	14
State and local governments	1,239	1,107	1,024	916	754	690	626	616	546	496	476	12	10
Industry	984	870	789	699	559	475	388	337	291	236	194	13	18
Other sources	**1,083**	**941**	**831**	**735**	**695**	**615**	**577**	**492**	**436**	**403**	**366**	15	11
TOTAL	**$14,987**	**$13,465**	**$12,153**	**$10,926**	**$9686**	**$8617**	**$7877**	**$7323**	**$6846**	**$6077**	**$5380**	11%	11%

Note: Data for institutional fiscal years. **Source:** National Science Foundation

FIELDS OF UNIVERSITY R&D SPENDING: Boost for chemical engineering in 1989

$ Millions	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	Annual change 1988–89	Annual change 1979–89
All sciences	**$12,600**	**$11,374**	**$10,266**	**$ 9,287**	**$8271**	**$7388**	**$6746**	**$6281**	**$5861**	**$5196**	**$4593**	11%	11%
Life	8,080	7,258	6,533	5,893	5282	4713	4304	4016	3689	3218	2833	11	11
Physical	1,643	1,547	1,391	1,286	1148	1000	900	823	765	678	602	6	11
Physics	773	732	667	630	551	474	417	367	357	322	292	6	10
Chemistry	610	568	513	469	421	371	335	308	285	245	206	7	11
Environmental	983	885	831	773	703	644	616	557	550	509	453	11	8
Psychology and social	874	767	690	633	541	504	480	484	494	453	396	14	8
Computer	468	411	373	323	283	225	176	149	132	114	98	14	17
Mathematical	214	199	177	152	128	123	106	96	87	79	79	8	10
Others	337	307	272	228	186	179	165	156	145	146	134	10	10
Engineering	**2,388**	**2,091**	**1,887**	**1,638**	**1415**	**1229**	**1130**	**1041**	**968**	**866**	**768**	**14**	**12**
Chemical	185	154	141	126	110	96	91	84	76	68	na	20	—
TOTAL	**$14,987**	**$13,465**	**$12,153**	**$10,926**	**$9686**	**$8617**	**$7877**	**$7323**	**$6829**	**$6062**	**$5361**	11%	11%
ANNUAL CHANGE	11%	11%	11%	13%	12%	9%	8%	7%	13%	13%	16%		

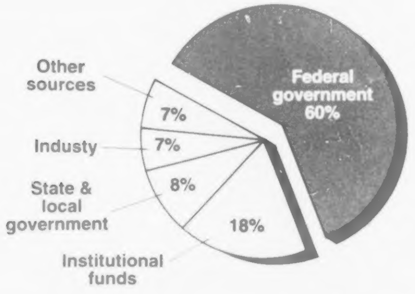
Note: Data for institutional fiscal years. Data since 1981 were revised in 1989. **na** = not available. **Source:** National Science Foundation

FEDERALLY FINANCED R&D SPENDING AT UNIVERSITIES: Growth slows for physical sciences

$ Millions	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	Annual change 1988–89	Annual change 1979–89
All sciences	**$7593**	**$6956**	**$6224**	**$5726**	**$5191**	**$4637**	**$4238**	**$4059**	**$3898**	**$3500**	**$3069**	9%	9%
Life	4773	4318	3830	3488	3184	2827	2586	2502	2365	2094	1819	11	10
Physical	1195	1153	1048	982	890	782	699	650	619	555	491	4	9
Physics	598	576	531	510	453	390	343	307	309	280	253	4	9
Chemistry	424	405	368	338	313	279	247	230	217	190	157	5	10
Environmental	645	583	541	515	473	445	426	391	391	372	329	11	7
Psychology and social	367	329	293	287	260	241	236	250	280	263	227	12	5
Computer	318	289	257	232	196	163	128	107	93	77	69	10	17
Mathematical	156	149	131	114	97	92	76	72	68	61	60	5	10
Others	139	133	125	107	92	87	87	88	82	78	73	5	7
Engineering	**1380**	**1225**	**1109**	**976**	**865**	**787**	**744**	**703**	**662**	**596**	**526**	**13**	**10**
Chemical	93	78	70	68	59	55	53	50	48	46	na	19	—
TOTAL	**$8972**	**$8181**	**$7333**	**$6702**	**$6056**	**$5423**	**$4983**	**$4763**	**$4561**	**$4096**	**$3595**	10%	10%
ANNUAL CHANGE	10%	12%	9%	11%	12%	9%	5%	4%	11%	14%	18%		

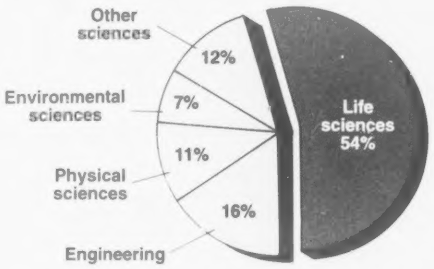
Note: Data for institutional fiscal years. Data since 1981 were revised in 1989. **na** = not available. **Source:** National Science Foundation

Federal government funds 60% of all academic R&D



Fiscal 1989 academic R&D expenditures = $15 billion

Life sciences account for more than half of academic R&D



Fiscal 1989 academic R&D expenditures = $15 billion

Source: National Science Foundation

TOP 10 UNIVERSITY R&D CENTERS: Three labs get 63% of total federal support

$ Millions, fiscal 1989	Physical sciences	Engineering	Math & computer sciences	Environmental sciences	Life sciences	Psychology & social sciences	Other sciences	Total
1 Jet Propulsion Lab	$ 118.0	$ 446.9	$419.2	$ 94.7	$ 0	$ 0	$0	$1078.8
2 Lawrence Livermore National Lab	308.7	483.8	151.0	31.8	29.3	0	0	1004.6
3 Los Alamos National Lab	447.5	311.3	78.7	5.8	33.2	22.8	3.1	902.4
4 Lincoln Lab	69.7	256.2	37.8	0	0	0.4	0	364.1
5 Argonne National Lab	104.2	140.2	5.1	81.9	12.0	0	0	343.3
6 Brookhaven National Lab	186.2	38.7	0.6	7.8	21.2	0.4	0.2	255.2
7 Lawrence Berkeley Lab	146.5	0.2	1.9	10.8	28.7	0	5.1	193.2
8 Fermi National Accelerator Lab	185.1	0	0	0	4.5	0	0	185.1
9 Plasma Physics Lab	112.6	0	0	0	0	0	0	112.6
10 Stanford Linear Accelerator Center	108.7	0	0	0	0	0	0	108.7
All others	81.6	4.1	22.6	65.7	6.2	0.6	0	180.8
TOTAL, ALL FEDERALLY FUNDED R&D CENTERS	**$1868.7**	**$1681.4**	**$716.8**	**$298.5**	**$130.6**	**$24.2**	**$8.4**	**$4728.6**

Note: Data for university-administered, federally funded R&D centers. A number of institutions have developed or are in the process of developing new computer systems and methodologies that enable them to report more accurately the total cost of science and engineering research. Fiscal 1989 comparisons with data reported in earlier years may be inappropriate in some areas. **Source:** National Science Foundation

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CAPITAL SPENDING AT UNIVERSITIES: Environmental sciences make big gain in 1989

$ Millions	1989							Annual change	
	Total spending	% federal funds	1988	1987	1986	1985	1984	1988–89	1984–89
All sciences	**$1719.9**	**9%**	**$1589.3**	**$1357.3**	**$1179.4**	**$1039.1**	**$1027.8**	**8%**	**11%**
Life sciences	1161.9	7	1050.0	909.0	768.3	691.1	716.6	11	10
Physical sciences	237.7	17	204.9	156.8	143.7	115.7	110.1	16	17
Mathematical and computer sciences	67.5	11	95.4	82.7	90.6	77.2	48.9	−29	7
Psychology and social sciences	91.4	11	92.8	64.9	67.7	73.5	78.3	−2	3
Environmental sciences	72.7	26	58.7	54.1	48.9	54.6	36.2	24	15
Other sciences	88.8	10	87.4	89.9	60.1	27.0	37.6	2	19
Engineering	**371.8**	**12**	**365.3**	**379.8**	**314.1**	**183.6**	**146.9**	**2**	**20**
TOTAL	**$2091.7**	**11%**	**$1954.6**	**$1737.1**	**$1493.5**	**$1222.7**	**$1174.6**	**7%**	**12%**
ANNUAL CHANGE	**7%**	**—**	**13%**	**16%**	**22%**	**4%**	**8%**		

Note: Data for institutional fiscal years. Includes expenditures for facilities and equipment for research, development, and instruction. **Source:** National Science Foundation

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UNIVERSITY SPENDING FOR RESEARCH EQUIPMENT: Slight drop for physical sciences

$ Millions	1989		1988		1982		Annual change			
							1988–89		1982–89	
	Total	Federal funds	Total	Federal funds	Total	Federal funds	Total	Federal funds	Total	Federal funds
All sciences	**$792.9**	**$476.9**	**$725.4**	**$459.6**	**$350.1**	**$223.6**	**9%**	**4%**	**13%**	**11%**
Life sciences	**442.4**	**239.5**	**386.4**	**215.8**	**201.9**	**116.5**	**14**	**11**	**12**	**11**
Physical sciences	**179.4**	**131.7**	**180.9**	**142.1**	**79.6**	**63.8**	**−1**	**−7**	**12**	**11**
Physics	81.8	64.1	84.7	67.4	33.7	29.0	−3	−5	14	12
Chemistry	75.8	53.0	74.6	57.7	33.4	24.8	2	−8	12	11
Environmental sciences	**66.4**	**44.8**	**55.6**	**36.6**	**26.5**	**18.4**	**19**	**22**	**13**	**14**
Mathematical and computer sciences	**52.9**	**35.9**	**54.1**	**42.2**	**18.3**	**12.4**	**−2**	**−15**	**16**	**16**
Other sciences	**51.8**	**25.0**	**48.5**	**22.9**	**21.8**	**12.5**	**7**	**9**	**13**	**10**
Engineering	**205.0**	**117.3**	**195.7**	**117.8**	**71.3**	**46.9**	**5**	**0**	**16**	**14**
Chemical	18.6	9.5	15.0	8.0	6.6	3.8	24	19	16	14
TOTAL	**$997.9**	**$594.2**	**$921.1**	**$577.4**	**$421.4**	**$270.4**	**8%**	**3%**	**13%**	**12%**

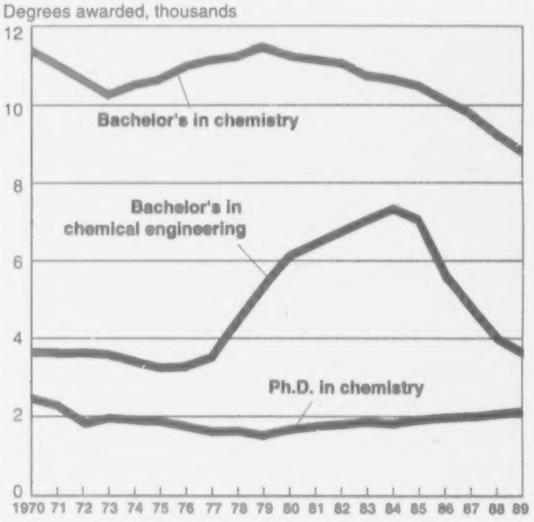
Note: Data for institutional fiscal years. **Source:** National Science Foundation

CHEMICAL DEGREES: Annual production of B.S. chemists down 26% from 1979 peak

Academic year	Degrees awarded in chemistry			Degrees awarded in chemical engineering		
	Bachelor's	Master's	Ph.D.	Bachelor's	Master's	Ph.D.
1970	11,617	2146	2208	3720	1045	438
1971	11,183	2284	2160	3615	1100	406
1972	10,721	2259	1971	3663	1154	394
1973	10,226	2230	1882	3636	1051	397
1974	10,525	2138	1828	3454	1045	400
1975	10,649	2006	1824	3142	990	346
1976	11,107	1796	1623	3203	1031	308
1977	11,322	1775	1571	3581	1086	291
1978	11,474	1892	1525	4615	1237	259
1979	11,643	1765	1518	5655	1149	304
1980	11,446	1733	1551	6383	1271	284
1981	11,347	1654	1622	6527	1267	300
1982	11,062	1751	1722	6740	1285	311
1983	10,746	1604	1746	7145	1304	319
1984	10,704	1667	1744	7475	1514	330
1985	10,482	1719	1789	7146	1544	418
1986	10,116	1754	1908	5877	1361	446
1987	9,661	1738	1976	4983	1184	497
1988	9,052	1708	1995	3917	1088	579
1989	8,654	1785	2034	3684	1097	599

Source: National Center for Education Statistics

Another slight gain for chemistry Ph.D.s



Note: Academic years. **Source:** National Center for Education Statistics

TOP 10 UNIVERSITIES IN R&D SPENDING: Ten schools spend 20% of total

$ Millions, fiscal 1989	Physical sciences	Chemistry[a]	Engineering	Environmental sciences	Life sciences	Math & computer sciences	Other sciences	Total
1 Johns Hopkins U	$ 85.8	$ 5.2	$ 209.7	$ 44.0	$ 180.1	$104.8	$ 23.9	**$ 648.4**
2 Massachusetts Institute of Technology	89.9	14.0	116.4	11.6	34.3	13.6	21.4	**287.2**
3 Cornell U	43.2	10.2	38.6	5.5	163.6	21.5	14.2	**286.7**
4 Stanford U	50.7	10.1	78.3	5.2	129.4	15.7	6.8	**286.0**
5 U of Wisconsin, Madison	27.2	8.3	34.7	20.9	165.1	8.5	29.5	**286.0**
6 U of Michigan	15.7	3.8	46.7	16.1	143.2	8.1	50.8	**280.9**
7 U of Minnesota	14.4	5.9	27.7	7.2	187.3	6.7	15.3	**258.6**
8 Texas A&M U	19.7	9.8	52.5	52.2	103.0	4.0	19.2	**250.7**
9 U of California, Los Angeles	21.8	9.9	23.0	11.3	144.9	6.6	20.3	**227.8**
10 U of Washington	13.4	5.2	16.7	19.2	136.2	8.3	28.0	**221.7**
TOTAL, FIRST 10 INSTITUTIONS	**$ 382.0**	**$ 83.3**	**$ 644.6**	**$193.2**	**$1387.2**	**$197.8**	**$ 229.3**	**$ 3,034.0**
TOTAL, ALL INSTITUTIONS	**$1643.4**	**$610.4**	**$2387.6**	**$982.9**	**$8079.9**	**$682.0**	**$1211.5**	**$14,987.3**

Note: Data for institutional fiscal years. A number of institutions have developed or are in the process of developing new computer systems and methodologies that enable them to report more accurately the total cost of science and engineering research. Fiscal 1989 comparisons with data reported in earlier years may be inappropriate in some areas. **a** Included in physical sciences. **Source:** National Science Foundation

SCHOOLS SPENDING MOST ON CHEMICAL R&D: 18% of total goes to 10 institutions

Rank 1989	Rank 1988		1989 Total spending ($ thousands)	1989 % federal funds	1988	1987	1986	1985	1984	Annual change 1988–89	Annual change 1984–89
					($ thousands)						
1	2	**Massachusetts Inst. of Technology**	$ 15,031	89%	$ 13,287	$ 11,471	$ 13,593	$ 13,221	$ 11,741	13%	5%
2	1	**U of California, Berkeley**	12,663	91	14,285	12,490	9,114	10,804	7,850	−11	10
3	7	**Harvard U**	11,856	89	9,886	8,895	7,202	6,557[a]	6,307[a]	20	13
4	3	**U of Texas, Austin**	11,484	53	10,943	11,420	8,531	7,908	6,639	5	12
5	5	**Cornell U**	10,217	73	10,472	8,397	7,376	7,962	6,710	−2	9
6	4	**Stanford U**	10,098	88	10,547	8,916	8,340	8,354	6,809	−4	8
7	8	**U of California, Los Angeles**	9,855	92	9,519	10,099	7,954	7,243	7,219	4	6
8	9	**Texas A&M U**	9,808	45	8,785	7,462	7,230[a]	6,768[a]	5,606[a]	16	12
9	12	**U of Maryland, College Park**	9,732	39	8,545	9,258	7,904	7,289	6,324	14	9
10	14	**U of Chicago**	9,333	92	8,046	7,514	7,553[a]	6,921[a]	5,735	16	10
		Total, first 10 institutions	$110,077	76%	$104,315	$ 95,922	$ 84,797	$ 83,027	$ 70,940	6%	9%
11	6	**California Inst. of Technology**	9,235	81	9,931	10,870	9,176	7,605	6,446	−7	7
12	10	**U of Illinois, Urbana**	9,208	71	8,647	9,035	8,604	7,079	6,284	6	8
13	13	**Princeton U**	8,873	64	8,087	6,477	5,702	3,963	3.670	10	19
14	11	**Purdue U**	8,769	81	8,615	7,092	6,315	6,018	5,443	2	10
15	17	**Pennsylvania State U**	8,616	76	7,739	6,072	6,438	6,509	5,124	11	11
16	20	**U of Wisconsin, Madison**	8,326	66	7,282	6,984	7,892	7,350	6,076	14	7
17	15	**Case Western Reserve U**	8,233	63	7,996	7,164	2,922[a]	2,802	2,759	3	24
18	16	**Indiana U**	7,927	77	7,991	6,181	6,110	5,820	5,551	−1	7
19	28	**Rutgers U**	7,905	83	5,926	3,913	3,507	2,368	2,301	33	28
20	19	**U of Pennsylvania**	7,760	91	7,292	6,741	6,064	5,025	4,375	6	12
		Total, first 20 institutions	$194,929	76%	$183,821	$166,451	$147,527	$137,566	$118,969	6%	10%
21	26	**Northwestern U**	7,661	73	6,644	6,095	4,826	5,062	4,557	15	11
22	22	**Rockefeller U**	7,471	50	6,975	6,823	7,335	4,826[a]	1,178	7	45
23	23	**Columbia U, main division**	7,120[a]	94	6,931	6,715	5,555	5,188	4,662	3	9
24	18	**Ohio State U**	6,771	66	7,568	5,755	6,546	5,422	4,104	−11	11
25	21	**U of Notre Dame**	6,660	90	7,004	5,550	5,402	5,549	4,760	0	7
26	29	**U of Colorado**	6,587	82	5,637	5,118	5,830	6,360	4,134	17	7
27	25	**U of California, San Diego**	6,487	89	6,780	5,179	6,535	4,642	4,355	−4	8
28	24	**Yale U**	5,915	85	6,869	5,538	6,169[a]	5,600[a]	4,134	−14	7
29	33	**U of Minnesota**	5,863	86	5,232	5,426	5,110	4,167	4,067	12	8
30	30	**U of Pittsburgh**	5,736	79	5,598	5,105	4,974	4,580	3,965	2	8
		Total, first 30 institutions	$261,200	76%	$249,059	$233,755	$205,809	$188,962	$158,885	5%	10%
31	39	**U of Utah**	5,653	68	4,600	4,846	5,354	4,840	3,830	23	8
32	40	**Wayne State U**	5,557	54	4,582	3,278	3,405	2,903	3,071	21	13
33	31	**U of Oregon**	5,501	81	5,550	4,462	5,087	4,640	4,255	−1	5
34	46	**Florida State U**	5,382	37	4,308	3,841	4,047	3,276	3,137	25	11
35	27	**Georgia Inst. of Technology**	5,380	56	5,989	4,889	5,260	3,684	3,846	−10	7
36	62	**Arizona State U**	5,260	60	4,306	3,586	4,124	2,703	2.875	22	13
37	45	**U of Washington**	5,192	72	4,338	3,655	2,971	2,964	2,340	20	17
38	43	**U of North Carolina, Chapel Hill**	5,171	88	4,476	3,471	3,352	3,386	2,945	16	12
39	38	**Virginia Polytechnic Inst. & State U**	5,155	43	4,735	4,190	3,786	4,840	3,830	9	6
40	34	**Johns Hopkins U**	5,152	94	5,211	5,593	5,506	4,652[a]	4,030	−1	5
		Total, first 40 institutions	$314,603	75%	$297,154	$265,566	$248,701	$226,850	$193,044	6%	10%
41	48	**U of Virginia**	5,096	82	4,153	4,169	3,436	3,046	2,516	23	15
42	35	**U of Florida**	5,061	56	5,030	5,690	4,750	4,380	4,024	1	5
43	51	**U of Tennessee System**	4,960	60	3,962	2,611	2,501	na	na	25	–
44	56	**U of Kansas**	4,952	41	3,845	2,803	1,818	1,875[b]	1,405[b]	29	29
45	61	**U of Houston**	4,908	43	3,693	4,003	3,225	2,722	2,117	33	18
46	44	**U of Rochester**	4,762	91	4,437	3,545	3,584	3,196	3,858	7	4
47	36	**State U of New York, Stony Brook**	4,754	76	5,010	3,669	3,333	3,481	3,084	−5	9
48	57	**Louisiana State U**	4,698	48	3,834	3,446	3,195	2,664	1,438	23	27
49	50	**U of Cincinnati**	4,655	59	4,008	3,816	1,684	1,593	1,633	16	23
50	54	**State U of New York, Buffalo**	4,644	60	3,903	3,370	2,837	2,768	2,407	19	14
		Total, first 50 institutions	$363,093	73%	$339,029	$302,688	$279,064	$252,575	$215,526	7%	11%
		NATIONAL TOTAL	$610,394	69%	$567,822	$513,102	$469,275	$421,506	$369,945	7%	11%

Note: Data for institutional fiscal years. A number of institutions have developed or are in the process of developing new computer systems and methodologies that enable them to report more accurately the total cost of science and engineering research. Fiscal-year 1989 comparisons with data reported in earlier years may be inappropriate in some areas. Data for 1986 and later were revised in 1989. **a** Estimated. **b** Imputed. **na** = not available. **Source:** National Science Foundation

SCHOOLS WITH MOST FEDERAL SUPPORT FOR CHEMICAL R&D: **Three get over $10 million each**

Rank			1989	1988	1987	1986	1985	1984	Annual change	
1989	1988		($ thousands)						1988–89	1984–89
1	2	**Massachusetts Inst. of Technology**	$ 13,333	$ 11,987	$ 10,656	$ 12,909	$ 12,424	$ 11,055	11%	4%
2	1	**U of California, Berkeley**	11,450	12,998	11,160	8,258	9,892	7,263	−12	10
3	4	**Harvard U**	10,594	9,272	8,309	6,748	6,557	6,307	14	11
4	5	**U of California, Los Angeles**	9,024	8,885	9,414	7,516	6,389	5,047	2	12
5	3	**Stanford U**	8,878	9,423	7,918	7,524	7,097	6,120	−6	8
6	8	**U of Chicago**	8,621	7,235	6,499	6,769[a]	6,265[a]	5,116	19	11
7	6	**California Inst. of Technology**	7,459	8,769	9,922	7,612	7,001	5,810	−15	5
8	7	**Cornell U**	7,458	8,269	6,753	5,934	6,293	5,775	−10	5
9	9	**Purdue U**	7,102	7,120	5,978	5,708	5,418	4,452	0	10
10	14	**U of Pennsylvania**	7,046	6,337	5,653	5,232	4,398	3,921	12	12
		Total, first 10 institutions	$ 90,965	$ 90,295	$ 82,262	$ 74,210	$ 71,734	$ 60,866	1%	8%
11	11	**Columbia U, main division**	6,676	6,519	6,625	5,030	4,490	4,639	2	8
12	39	**Rutgers U**	6,572	3,442	2,525	2,123	2,055	2,129	91	25
13	15	**U of Illinois, Urbana**	6,566	6,193	6,306	5,999	5,371	5,005	6	6
14	17	**Pennsylvania State U**	6,515	5,957	4,915	5,161	5,860	4,564	9	7
15	13	**Indiana U**	6,127	6,354	4,923	4,757	4,885	4,694	−4	10
16	12	**U of Texas, Austin**	6,120	6,443	6,405	4,922	4,741	3,873	−5	10
17	10	**U of Notre Dame**	5,983	6,557	5,158	4,998	5,097	4,416	−9	6
18	16	**U of California, San Diego**	5,757	6,161	4,599	5,918	4,053	3,780	−7	9
19	19	**Princeton U**	5,681	5,812	5,064	4,575	3,104	2,892	−2	14
20	22	**Northwestern U**	5,577	4,955	4,641	3,753	3,963	3,471	13	10
		Total, first 20 institutions	$152,539	$148,688	$133,423	$121,446	$115,353	$100,329	3%	9%
21	24	**U of Wisconsin, Madison**	5,505	4,939	4,718	5,348	5,156	4,391	11	5
22	27	**U of Colorado**	5,418	4,603	4,402	4,911	5,430	3,358	18	10
23	21	**Case Western Reserve U**	5,161	5,433	5,016	2,062	2,065	1,904	−5	22
24	32	**U of Minnesota**	5,054	4,156	4,395	4,013	3,295	3,346	22	9
25	18	**Yale U**	5,011	5,927	4,909	5,566[a]	5,095[a]	3,528	−15	7
26	25	**Johns Hopkins U**	4,824	4,830	5,116	4,903	4,155	3,783	0	5
27	26	**U of Pittsburgh**	4,558	4,803	4,028	4,045	3,836	3,343	−5	6
28	31	**U of North Carolina, Chapel Hill**	4,534	4,193	3,153	2,929	2,885	2,699	8	11
29	20	**Ohio State U**	4,445	5,437	4,517	4,931	3,846	2,904	−18	9
30	28	**U of Oregon**	4,435	4,519	3,579	4,345	3,959	3,524	−2	5
		Total, first 30 institutions	$201,484	$197,528	$177,256	$164,499	$155,075	$133,109	2%	9%
31	23	**Texas A&M U**	4,408	4,945	4,019	3,128	4,195	2,735	−11	10
32	33	**U of Rochester**	4,327	3,936	3,275	3,336	2,861	3,490	10	4
33	40	**U of Virginia**	4,165	3,419	3,281	2,748	2,165	2,099	22	15
34	37	**U of Southern California**	3,986	3,568	2,903	2,857	2,149	2,495	12	10
35	35	**U of Utah**	3,872	3,614	4,194	4,791	4,426	3,380	7	3
36	34	**U of Maryland, College Park**	3,844	3,793	4,073	3,557	3,323	2,862	1	6
37	47	**U of Washington**	3,756	2,904	2,287	1,898	1,738	1,843	29	15
38	45	**Rockefeller U**	3,713	3,082	3,247	3,377	2,553	833	20	35
39	29	**U of California, Irvine**	3,685	4,376	3,386	3,394	3,035	2,096	−16	12
40	38	**State U of New York, Stony Brook**	3,610	3,460	2,930	2,168[a]	2,343	2,069	4	12
		Total, first 40 institutions	$240,850	$234,525	$210,851	$195,753	$183,863	$157,011	3%	9%
41	30	**Colorado State U**	3,457	4,280	3,273	3,403	2,434	2,426	−19	7
42	58	**U of California, Davis**	3,386	2,255	1,980	2,175	1,702	1,478	50	18
43	43	**U of California, Santa Barbara**	3,242	3,196	3,526	3,087	2,709	1,881	1	12
44	51	**Arizona State U**	3,172	2,813	2,317	2,218	2,306	2,014	13	10
45	60	**Georgetown U**	3,113	2,148	2,155	2,252	1,075	822	45	31
46	57	**Washington U**	3,088	2,291	1,759	1,477	1,547	1,629	35	14
47	48	**U of Arizona**	3,044	2,885	2,499	2,291	1,738	1,843	6	11
48	41	**U of Michigan**	3,022	3,310	2,615	2,367	2,286	2,356	−9	5
49	36	**Georgia Inst. of Technology**	3,020	3,574	2,565	2,914	2,051	2,227	−16	6
50	59	**Wayne State U**	2,989	2,151	1,770	1,690	2,076	2,104	39	7
		Total, first 50 institutions	$272,383	$263,528	$235,310	$219,627	$203,787	$175,791	3%	9%
		NATIONAL TOTAL	$425,211	$405,017	$367,753	$338,027	$312,831	$278,215	5%	9%

Note: Data for institutional fiscal years. A number of institutions have developed or are in the process of developing new computer systems and methodologies that enable them to report more accurately the total cost of science and engineering research. Fiscal-year 1989 comparisons with data reported in earlier years may be inappropriate in some areas. Data for 1986 and later were revised in 1989. a Estimated. **Source:** National Science Foundation

SCHOOLS SPENDING MOST ON CHEMICAL ENGINEERING R&D: MIT way out in front

Rank 1989	Rank 1988		Chemical engineering: Total spending ($ thousands)	Chemical engineering: Federal funds	Chemical engineering: % federal funds	All engineering: Total spending ($ thousands)	All engineering: Federal funds	All engineering: % federal funds
1	1	**Massachusetts Inst. of Technology**	$ 13,493	$ 9,359	69%	$ 116,367	$ 80,356	69%
2	2	**U of Minnesota**	8,403	5,279	63	27,709	10,421	38
3	3	**U of Texas, Austin**	6,109	2,253	37	50,944	22,894	45
4	14	**Columbia U, main division**	5,308	3,059	58	15,429	9,386	62
5	6	**Johns Hopkins U**	4,842	4,352	90	209,748	206,629	99
6	5	**U of Maryland, College Park**	4,548	1,514	33	41,624	15,655	38
7	17	**U of Pennsylvania**	4,355	3,452	79	9,981	6,439	65
8	4	**Texas A&M U**	4,159	706	17	52,541	14,743	28
9	9	**U of Wisconsin, Madison**	3,839	2,096	55	34,697	21,745	63
10	11	**Case Western Reserve U**	3,378	2,104	62	18,089	13,173	73
		Total, first 10 institutions	$ 58,434	$34,174	58%	$ 576,769	$ 401,441	70%
11	7	**North Carolina State U, Raleigh**	3,304	861	26	34,421	11,209	33
12	12	**U of Delaware**	3,147	895	28	10,874	4,461	41
13	8	**Stanford U**	2,939	2,564	87	78,311	65,502	84
14	10	**Brigham Young U**	2,867[a]	2,290[a]	80	5,127[a]	3,231[a]	63
15	19	**Lehigh U**	2,742	523	19	18,214	6,186	34
16	15	**Pennsylvania State U**	2,674	991	37	97,276	59,260	61
17	26	**U of Houston**	2,396	994	41	8,020	3,137	39
18	18	**Princeton U**	2,367	1,103	47	20,957	10,508	50
19	22	**U of California, Los Angeles**	2,238	1,597	71	22,975	16,679	73
20	24	**Auburn U**	2,217	754	34	16,996	7,664	45
		Total, first 20 institutions	$ 85,325	$46,746	55%	$ 889,940	$ 589,278	66%
21	13	**U of Michigan**	2,207	1,482	67	46,866	27,507	59
22	16	**Cornell U**	2,206	1,250	57	38,648	22,630	59
23	34	**U of Oklahoma**	2,189	505	23	8,529	2,247	26
24	20	**Georgia Inst. of Technology**	2,124	1,192	56	116,109	65,178	56
25	21	**California Inst. of Technology**	2,047	1,635	80	16,670	13,641	82
26	23	**Purdue U**	2,042	1,245	61	32,873	18,733	57
27	47	**Rutgers U**	2,034	722	35	19,463	3,680	19
28	25	**U of Washington**	2,022	1,097	54	16,738	10,581	63
29	29	**New Mexico Inst. of Mining & Tech.**	2,017	366	18	16,325	4,378	27
30	52	**Louisiana State U**	2,015	788	39	13,216	2,979	23
		Total, first 30 institutions	$106,228	$57,028	54%	$1,215,377	$ 760,832	63%
		NATIONAL TOTAL	$185,087	$92,947	50%	$2,387,593	$1,379,664	58%

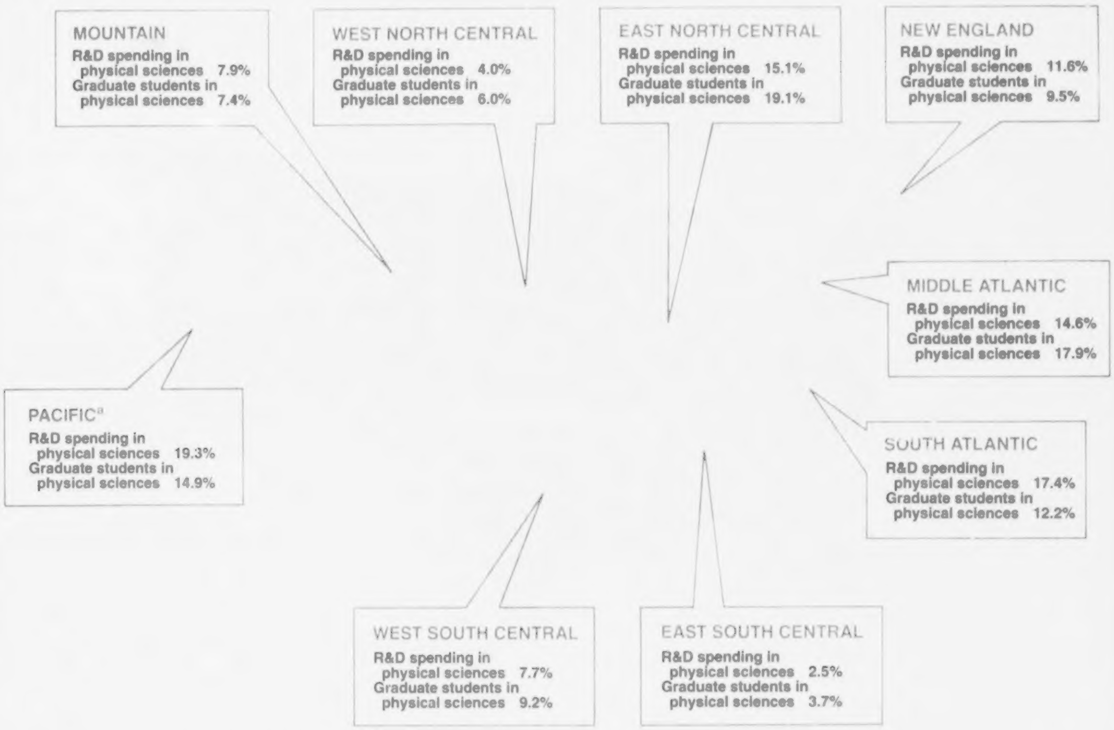
Note: Data for fiscal 1989. **a** Estimated. **Source:** National Science Foundation

FOREIGN GRADUATE STUDENTS: Most common in engineering, physics, and math

	1989		1988		1987		1986		1985		1984		Annual change	
	Thousands	% of total	Thousands	% of total	Thousands	% of total	Thousands	% of total	Thousands	% of total	Thousands	% of total	1988–89	1984–89
All sciences	**51.1**	**28%**	**49.1**	**28%**	**46.0**	**27%**	**43.5**	**26%**	**39.7**	**24%**	**36.1**	**22%**	**4%**	**7%**
Psychology and social sciences	13.5	20	13.6	21	12.8	20	12.4	20	11.8	19	10.8	18	−1	5
Mathematical and computer sciences	12.1	44	11.6	44	11.0	42	10.4	41	9.5	41	8.3	40	4	8
Biological sciences	9.9	25	8.9	23	7.9	21	7.0	19	6.2	17	5.6	16	11	12
Biochemistry	1.5	30	1.3	28	1.2	26	1.1	23	1.0	22	0.8	20	15	13
Physical sciences	10.9	38	10.2	37	9.8	35	9.3	34	8.3	32	7.4	30	7	8
Chemistry	5.6	35	5.2	33	4.8	31	4.4	28	4.0	26	3.5	24	8	10
Physics	5.1	44	4.9	43	4.8	43	4.7	44	4.1	41	3.8	38	4	6
Agricultural sciences	2.5	29	2.5	30	2.5	30	2.5	28	2.3	26	2.3	25	0	2
Earth, atmospheric, and ocean sciences	2.3	24	2.1	22	1.9	19	1.9	17	1.6	15	1.6	14	9	8
Engineering	**29.1**	**47**	**28.8**	**47**	**27.4**	**45**	**26.4**	**45**	**23.5**	**43**	**22.6**	**42**	**1**	**5**
Chemical	2.6	49	2.4	45	2.3	41	2.2	39	2.2	40	2.1	37	8	4
Metallurgical and materials	1.8	49	1.6	48	1.6	47	1.5	45	1.3	42	1.2	42	12	8
TOTAL	**80.2**	**33%**	**77.9**	**33%**	**73.4**	**32%**	**69.9**	**31%**	**63.2**	**29%**	**58.7**	**27%**	**3%**	**6%**
ANNUAL CHANGE	3%		6%		5%		11%		8%		3%			

Note: Data are for full-time graduate students at Ph.D-granting institutions only. The percent of total is the percent of all full-time graduate students in each area who are foreign. **Source:** National Science Foundation

Physical sciences: East and West Coast schools get 63% of R&D funds, 55% of grad students



MOUNTAIN
R&D spending in physical sciences 7.9%
Graduate students in physical sciences 7.4%

WEST NORTH CENTRAL
R&D spending in physical sciences 4.0%
Graduate students in physical sciences 6.0%

EAST NORTH CENTRAL
R&D spending in physical sciences 15.1%
Graduate students in physical sciences 19.1%

NEW ENGLAND
R&D spending in physical sciences 11.6%
Graduate students in physical sciences 9.5%

MIDDLE ATLANTIC
R&D spending in physical sciences 14.6%
Graduate students in physical sciences 17.9%

PACIFIC[a]
R&D spending in physical sciences 19.3%
Graduate students in physical sciences 14.9%

SOUTH ATLANTIC
R&D spending in physical sciences 17.4%
Graduate students in physical sciences 12.2%

WEST SOUTH CENTRAL
R&D spending in physical sciences 7.7%
Graduate students in physical sciences 9.2%

EAST SOUTH CENTRAL
R&D spending in physical sciences 2.5%
Graduate students in physical sciences 3.7%

Key to map: Using the Middle Atlantic states as an example, 14.6% of all R&D expenditures in the physical sciences and 17.9% of all graduate students in physical sciences are in this area. The figures for funding apply to Ph.D.-granting universities and colleges only. The figures for students apply to all universities and colleges.

Note: Data are based on $1.6 billion of R&D expenditures and 35,584 graduate students in the physical sciences enrolled in colleges and universities during the 1989 fiscal year. **a** Includes Alaska, Hawaii, and outlying areas. **Source:** National Science Foundation

GRADUATE SCIENCE STUDENTS: Growth slow for chemistry as for all fields

Thousands	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	Annual change 1988–89	Annual change 1979–89
All sciences	241.9	237.4	233.6	230.1	226.1	220.5	220.4	220.7	217.1	227.1	219.8	2%	1%
Psychology and social sciences	97.7	94.7	93.0	90.7	90.3	89.1	92.1	96.5	98.1	109.7	105.8	3	−1
Biological sciences	45.8	44.6	43.6	43.4	42.5	42.0	41.6	41.9	42.1	42.7	42.6	3	1
Biochemistry	5.1	4.9	4.8	4.9	4.7	4.5	4.2	4.1	4.0	4.0	3.9	4	3
Mathematical and computer sciences	43.6	43.7	42.3	40.9	39.1	35.4	33.2	30.4	27.2	25.0	22.7	0	7
Physical sciences	31.7	31.2	31.0	30.5	29.3	28.4	27.7	26.5	25.8	25.4	24.9	2	2
Chemistry	17.7	17.5	17.7	17.6	17.2	16.6	16.5	15.8	15.3	15.1	14.9	1	2
Physics	13.1	12.8	12.3	12.0	11.3	11.0	10.5	10.0	9.9	9.6	9.3	2	3
Earth, atmospheric, and ocean sciences	12.6	12.9	13.4	14.0	14.2	14.3	14.3	13.8	13.1	12.8	12.6	−2	0
Agricultural sciences	10.4	10.3	10.3	10.7	10.7	11.3	11.5	11.6	11.4	11.6	11.3	1	−1
Engineering	97.0	96.7	97.0	95.8	90.2	87.1	85.3	78.2	74.4	70.1	67.2	0	4
Chemical	6.3	6.5	7.0	6.9	7.0	7.2	7.4	6.9	6.3	5.9	5.4	−3	2
Metallurgical and materials	4.4	4.2	4.2	4.0	3.8	3.6	3.3	3.0	3.0	2.8	2.7	5	5
Petroleum	0.7	0.7	0.8	0.7	0.8	0.7	0.7	0.6	0.5	0.5	0.4	0	6
TOTAL	338.9	334.1	330.6	325.9	316.3	307.6	305.7	298.9	292.0	297.3	287.0	1%	2%
ANNUAL CHANGE	1%	1%	1%	3%	3%	1%	2%	2%	−2%	4%	3%		

Note: Data for Ph.D-granting institutions only. Data for 1981 and later were revised in 1990. **Source:** National Science Foundation

U.S. Still Dominates in Worldwide R&D, But Germany, Japan Make Faster Progress

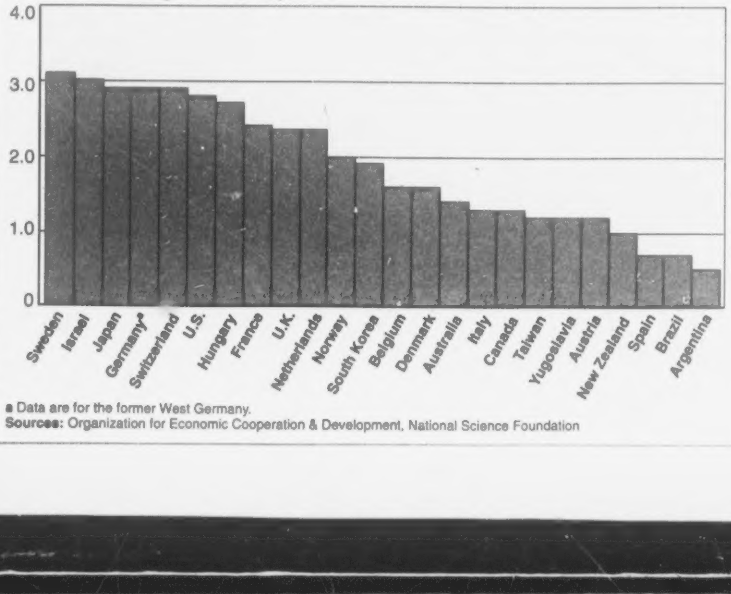
WORLDWIDE R&D SCIENTISTS AND ENGINEERS: **Japan's upswing continues**

Thousands	1989	1988	1987	1986	1985	1984	1983	1982	1981
U.S.	na	949	923	897	849	798	752	712	683
Japan[a]	458	435	416	393	381	357	347	na	na
Germany[b]	na	na	166	na	144	na	131	na	125
France	na	115	109	105	102	98	93	90	86
U.K.[c]	na	na	127	127	123	na	na	na	na
Italy	na	75	71	68	64	62	63	57	52
Canada	na	61	59	57	53	49	46	45	41
Netherlands	na	na	na	na	24	na	22	na	19
Sweden	na	na	23	na	22	na	19	na	18
Spain[d]	na	na	21	19	16	15	14	14	14
Norway	12	na	11	na	10	9	8	8	7
Denmark	na	11	10	9	9	8	8	7	7

Note: Table represents all scientists and engineers engaged in R&D on a full-time equivalent basis. **a** Revised to reflect full-time equivalent. **b** Data are for former West Germany. **c** Based on underestimated data because persons in the private nonprofit sector are excluded. **d** R&D personnel in the education sector include only researchers. **na** = not available.
Source: Organization for Economic Cooperation & Development

Only Sweden spends more than 3% of GNP on R&D

Total R&D as % of gross national product



a Data are for the former West Germany.
Sources: Organization for Economic Cooperation & Development, National Science Foundation

WORLDWIDE R&D EXPENDITURES: Five countries spend more than $10 billion on R&D annually

$ Millions, constant 1982		% of GNP
U.S. (1989)	$111,129	2.7%
Japan (1989)	45,906	3.0
Germany[a] (1989)	21,911	2.9
France (1989)	15,039	2.3
U.K. (1989)	13,196	2.2
Italy (1989)	8,183	1.3
Canada (1990)	5,486	1.3
Netherlands (1988)	3,632	2.2
Sweden (1989)	2,890	3.1

$ Millions, constant 1982		% of GNP
Switzerland (1989)	$2690	2.9%
India (1989)	2514	1.0
Australia (1988)	2413	1.4
Spain (1989)	2264	0.7
Belgium (1988)	1729	1.6
South Korea (1988)	1613	1.9
Taiwan (1988)	1555	1.2
Argentina (1988)	1326	0.5
Yugoslavia (1989)	1310	1.2

$ Millions, constant 1982		% of GNP
Austria (1991)	$1281	1.2%
Brazil (1987)	1275	0.7
Finland (1989)	1078	1.2
Norway (1989)	1066	2.0
Denmark (1989)	909	1.6
Israel (1983)	637	3.0
Hungary (1987)	588	2.7
New Zealand (1987)	296	1.0
Mexico (1987)	183	0.2

Note: Data are for the most current year available (in parentheses). Countries differ in statistical collection capabilities and definitions. In addition, some R&D/gross national product percentages are R&D/gross domestic product. Foreign currency conversions to U.S. dollars were calculated with Organization for Economic Cooperation & Development purchasing power parities or using International Monetary Fund average-for-period par/market exchange rates. **a** Data are for former West Germany. **Source:** National Science Foundation

TOTAL AND NONDEFENSE R&D: Japan's R&D spending doubled in past decade

												Annual change	
$ Billions, constant 1982	**1989**	**1988**	**1987**	**1986**	**1985**	**1984**	**1983**	**1982**	**1981**	**1980**	**1979**	**1988–89**	**1979–89**
TOTAL R&D													
U.S.	$111.1	$110.2	$106.8	$104.9	$102.5	$93.8	$85.8	$80.0	$76.6	$73.3	$70.1	1%	5%
Japan	45.9	42.0	39.1	36.5	36.1	32.6	30.1	27.7	25.8	23.4	21.2	9	8
Germany[a]	21.9	20.6	20.2	19.3	18.8	17.0	16.0	16.5	16.1	15.5	15.2	6	4
France	15.0	14.4	13.8	13.3	13.1	12.7	12.0	11.7	10.9	9.9	9.6	4	5
U.K.	13.2	13.5	13.6	13.5	12.8	na	11.9	na	12.2	na	na	−2	na
NONDEFENSE R&D													
U.S.	$ 78.7	$ 76.5	$ 72.7	$ 72.6	$ 71.9	$67.1	$62.2	$59.3	$58.0	$55.6	$52.8	3%	4%
Japan	45.5	41.7	38.8	36.2	35.9	32.4	29.9	27.5	25.7	23.4	21.2	9	8
Germany	20.9	19.7	19.2	18.3	17.9	16.2	15.3	15.8	15.4	14.7	14.4	6	4
France	11.8	11.2	10.8	10.6	10.5	9.9	9.4	9.1	8.2	7.7	7.5	5	5
U.K.	10.4	10.9	10.7	10.1	9.1	na	8.5	na	8.7	na	na	−5	na

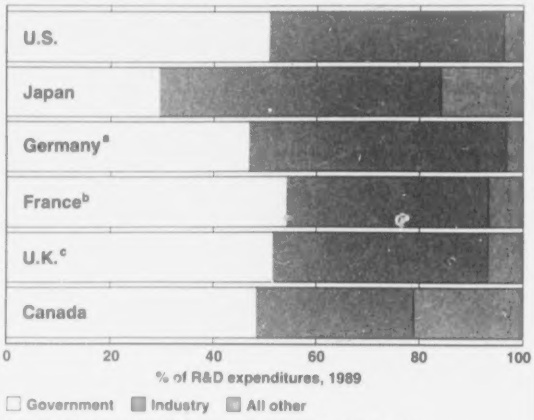
Note: Foreign currency conversions to U.S. dollars are calculated based on Organization for Economic Cooperation & Development purchasing power parity exchange rates. **a** Data are for former West Germany. **na** = not available. **Source:** National Science Foundation

ORIGIN OF CHEMICAL LITERATURE: Japan and China post steadily rising shares

% of total[a]	1990	1986	1982	1978	1974
U.S.	27.9%	27.7%	27.1%	26.6%	26.1%
U.S.S.R.	12.5	13.0	17.6	20.4	25.3
Japan	12.1	11.5	10.2	9.5	7.4
West Germany[b]	6.2	6.1	6.1	6.2	5.5
U.K.	5.5	5.6	5.9	6.0	6.0
China	4.5	3.1	1.8	0.2	0.0
France	4.2	4.3	4.1	4.0	4.2
Canada	3.0	3.1	2.7	2.6	2.7
India	2.9	3.0	3.3	3.0	2.6
Italy	2.3	2.4	2.3	2.0	2.0
Poland	1.5	1.8	1.5	2.2	2.1
Netherlands	1.5	1.4	1.3	1.2	1.0
Spain	1.5	1.3	0.9	0.6	0.5
Australia	1.2	1.3	1.3	1.3	1.1
East Germany[b]	1.2	1.2	1.2	1.4	1.1
Sweden	1.1	1.2	1.1	1.1	1.1
Czechoslovakia	1.0	1.2	1.3	1.4	1.6
Switzerland	1.0	1.1	1.1	1.0	1.0
All others	8.9	9.7	9.2	9.3	8.7
TOTAL PAPERS (THOUSANDS)	394.9	384.1	381.3	363.1	271.9

a Source of journal literature abstracted in *Chemical Abstracts* based on author's address. **b** Statistics for 1990 for entire year, even after reunification. **Source:** Chemical Abstracts Service

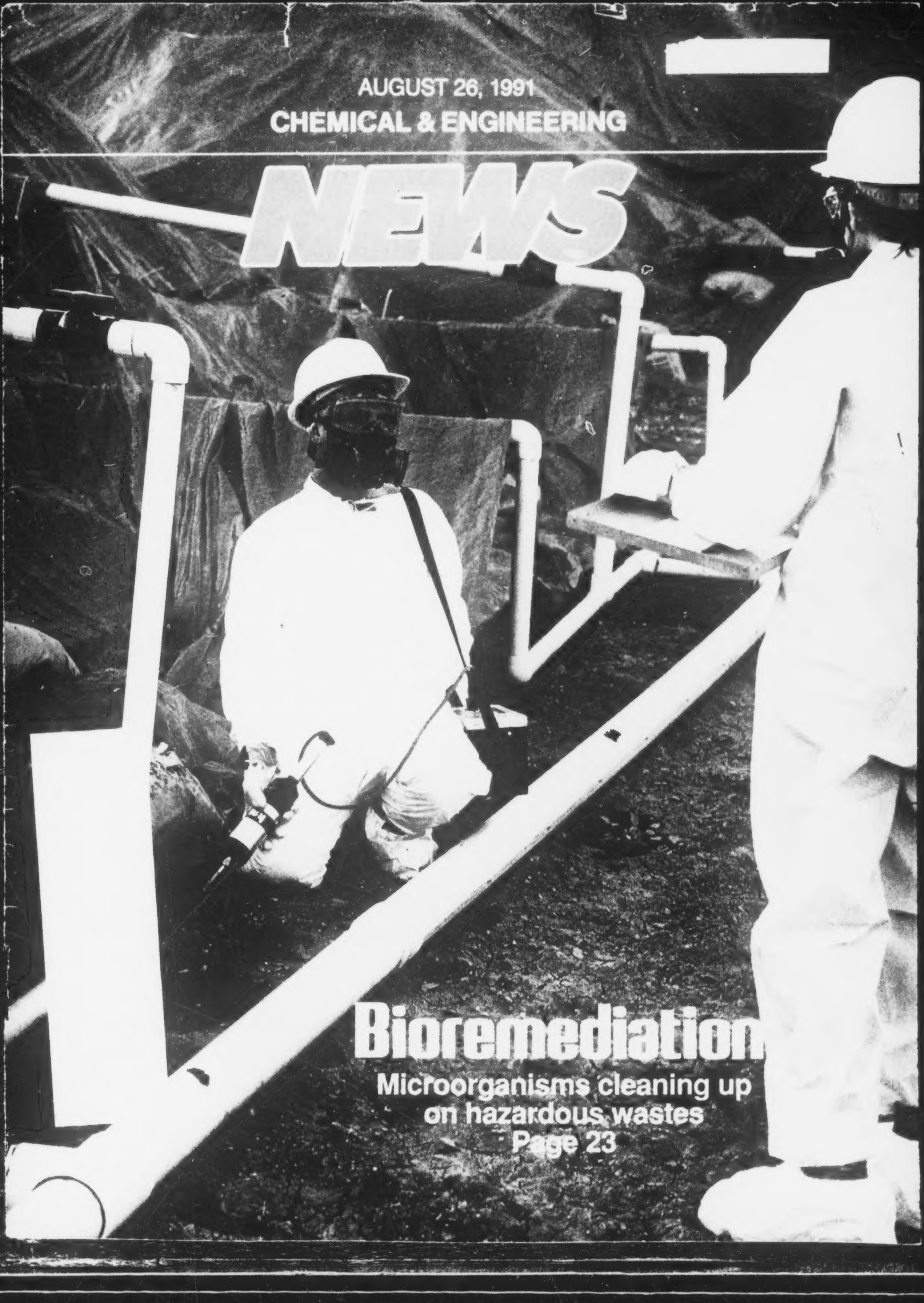
Industry provides the largest share of R&D funding in Japan and Germany



a Data are for former West Germany. **b** Estimated. **c** Data are for 1988.
Sources: Organization for Economic Cooperation & Development, National Science Foundation, individual nations

AUGUST 26, 1991

CHEMICAL & ENGINEERING NEWS



Bioremediation

Microorganisms cleaning up
on hazardous wastes

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CENEAR 69 (34) 1–68
ISSN 0009-2347

CHEMICAL & ENGINEERING
NEWS
AUGUST 26, 1991

News of the Week

- **Agreement signed requiring urban areas with excessive ozone and carbon monoxide pollution to start using oxygenated and reformulated gasoline.** Page 4
- **Eastman Kodak is seeking an injunction to stop Cetus Corp. from selling its polymerase chain reaction technology to Hoffmann-LaRoche.** Page 5
- **Chemical and rail industry groups step up efforts to tighten rules for transport of hazardous chemicals following recent tankcar spills in California.** Page 5
- **U.S.-Soviet cooperation in space research takes another step forward with launching of Soviet meteorological spacecraft carrying U.S.-made ozone mapping spectrometer.** Page 6

Cover: Engineered treatment cells speed up above-ground bioremediation of contaminated soils and sludges at Groundwater Technology Inc. site

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Business

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Government

Municipalities are battling to avoid paying for landfill cleanup under Superfund, arguing that companies are responsible for most hazardous wastes at these sites. **Page 16**

Woman convicted of poisoning her infant son with ethylene glycol is suing doctors and others for wrongful diagnosis, contending they should have discovered the baby had a rare genetic disease. **Page 18**

Study of Soviet-developed heart drug, moricizine, has been stopped because more patients taking it died than those who were taking a placebo. **Page 19**

Science/Technology

Common molecular target of two immunosuppressive drugs has been discovered by collaborating research groups at Stanford and Harvard universities. **Page 21**

Awards

1992 winners of American Chemical Society's national awards have been announced. **Page 52**

Product Report

Bioremediation—the microbial detoxification or degradation of wastes—is proving to be an innovative technology for cleaning up hazardous wastes. **Page 23**

Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036
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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
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Subscription Rates 1991: Printed editions: nonmembers U.S. 1 yr. $95, 2 yr. $171; outside U.S. 1 yr. $131, 2 yr. $243. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $12. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management: CENTCOM LTD.
(For list of offices see page 67)
Office of Ombudsman: (800) ACS-5558, No. 8-5

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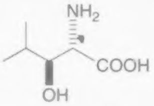
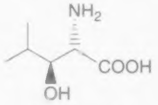
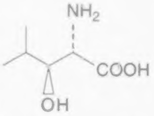
LETTERS

Racemic, scalemic, ambiscalemic

I concur with Takeshi Nakai (C&EN, July 1, page 2), who emphasizes the need for the facility to differentiate graphically between racemic and scalemic compounds. At the same time, however, I would like to remind Nakai that I published the graphic tools for precisely such a differentiation six years ago [*J. Chem. Educ.*, **62**, 114, (1985)].


(racemic)


(scalemic)


(ambiscalemic)

According to the proposal made in the cited article, three categories of compounds can be clearly delineated as shown by the examples. The term ambiscalemic is proposed as a descriptor for those scalemic substances with unknown absolute configurations.

Hubert Maehr
Roche Research Center
Nutley, N.J.

Starting with the practical

A letter from Rustum Roy attacking our huge expenditures on basic research (C&EN, May 6, page 6) was answered by Marco Ciufolini (C&EN, July 8, page 3), arguing that increased taxes will eventually pay back his research grants. Ciufolini might be effective in defending his own personal position, but I think he misses the main point of the Roy letter, which is that these types of funds could be spent even more efficiently in the future.

Before technological competition was so international, we Americans could afford to be the leaders in basic research. But now that the cumulative trade deficit threatens to make us an economic colony of Japan and Germany, some of us are beginning to realize that we will have to do better. Our consumer electronics and automobile industries are in serious trouble, and military power (and therefore freedom itself) seems dependent on similar technology. What worked in the past is no longer competitive.

The main point that I got out of the Roy letter could be paraphrased as, "Let the Japanese and Germans pay for the future C_{60}-type inventions. Let's read about them here in the U.S., and focus our efforts on efficiently mass producing them."

In order to actually implement this point, my own suggestion is to cut basic research funding by a large percentage. (Of course, this would require very unpleasant readjustments for many people, especially in the professorial ranks.) Spend some of the money on government-financed education for engineering and vocational students. If the education were free, better students (especially the well-rounded ones) would gravitate toward engineering instead of law, medicine, and business administration. We would then have more engineering-trained people ending up in management, as is now the case in both Japan and Germany.

Research that is paid for by the government must be more applied and less basic if we are going to survive as a world leader in anything other than Nobel Prize counts. Also, good teaching should be rewarded by government-paid bonuses. (In answer to the cry of, "Oh, but we can't judge good teaching," I say, take a poll of the top quarter of the students—the people who really want to learn can always tell you who the good teachers are.)

It is too bad that the letter from Roy started an argument in such emotional tones. However, monumental changes have to be made. Why not start with the practical things outlined above?

Daniel J. Shanefield
Distinguished Professor of Ceramic Engineering, Rutgers University

Keeping the word chemical

Apparently Ronald J. Gillespie's letter (C&EN, Dec. 10, 1990, page 4) produced several interesting responses dealing with the public's misunderstanding of the word chemical. I was glad to read in his most recent letter (C&EN, Aug. 5,

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Chemical Firms Offer Employees Expanded Child Care Programs

Du Pont, Dow, other firms are boosting so-called work and family benefits, find such programs pay off in increased productivity and morale

Susan J. Ainsworth, C&EN Houston

American business, chemical companies included, has long valued—or at least projected to esteem—honest employees and good family people. But until recently these corporations did little to nurture those values. They really didn't have to.

However, as the number of dual-income households grows and more women of childbearing age join the work force, corporate attitudes and policies are changing. At the center of these new "work and family" programs are expanding benefits that help their employees locate high-quality child care.

There is, of course, more than altruism at play. Besides the immeasurable public relations benefits, studies show that when companies help employees balance worker and parent responsibilities, turnover, absenteeism, and tardiness drop.

Moreover, experts report that these programs boost employee productivity and morale. "To be competitive, we must have a work force of people who find satisfaction in their total lives and who concentrate on the job. By helping employees meet some personal needs, we contribute to that concentration," says Jerry Fultz, employee relations manager at Phillips Petroleum.

Companies also hope that these programs will help them recruit top-notch employees now and in the future, when women and dual-career couples are expected to be an even larger percentage of the work force. "Demographic studies indicate that two thirds of the entrants into the work force between now and the year 2000 will be women, so I believe it's imperative that companies recognize this sort of aptitude, ability, and competence. Any company that continues to rely on white males as its primary source of management-track employees is going to have a very limited field to choose from in the future," says James L. Ketelsen, outgoing chairman and chief executive officer of Tenneco.

It's tough to say whether chemical companies as a whole are keeping pace with companies in all industries in providing child care benefits. Industry-specific data on this issue are hard to come by or are nonexistent. The chemical industry does tend to be "more conservative and cautious" compared with other industries when exploring new initiatives in family programs, notes Lynne Mischley, family issues coordinator for Dow Chemical.

Implementing these programs has "required development of our corporate culture," observes Susan Pierce, a consultant for work force partnering at Du Pont. Although Du Pont seems to be leading the chemical industry in its support and involvement in child care programs, "our old culture is still very much intact in some locations," she admits. "But it is changing quickly and we're working hard at it. I feel very good about it."

One child care option that chemical companies might be less likely to adopt than companies in other industries is on-site care. "We have a clear stance that we would not locate an on-site child care center within the gates of one of our plants," says Dow's Mischley. The way the chemical industry handles child care is slightly different from the way many other industries would handle it, "simply because it has a unique safety perspective," she points out.

But that does not now seem to be a major disadvantage, considering that relatively few U.S. corporations provide on-site child care centers anyway. According to a 1990 study done by benefits consulting firm Hewitt Associates, of Lincolnshire, Ill., 64% of the 837 employers it surveyed provide some type of child care benefit for their employees, but of those, only 9% provided or subsidized on-site or near-site child care centers.

At least some chemical companies have decided that an on-site center at one of their office complexes would not be a cost-effective or viable solu-

Companies offer spectrum of child care programs

Benefit	% of surveyed companies offering benefit
Dependent care spending accounts	89%
Resource and referral services	41
Child care centers	9
Employer-arranged discounts with local child care providers	4
Sick child care program	4
Voucher program	3
Financial support of outside child care facilities	3
Other (for example, direct subsidies, reimbursement for overtime)	2

Note: Figures are for 538 employers that provided some type of child care benefit for their employees in 1990. Total percentages exceed 100% because some employers offer multiple programs. **Source:** Hewitt Associates

Tenneco employees spend a few moments with their children at company-supported child care center

tion for their employees. Two years ago, for example, Air Products & Chemicals found that its Allentown, Pa., headquarters employees had 1400 children under the age of six. Trying to respond on a scale like that would be difficult, notes Pam Handwerk, manager for equal employment affairs and diversity programs at Air Products.

Meanwhile, other companies are not sure they'd have enough employee children to fill such centers. And fluctuations in this population of employee children would call to question a center's long-term utility. The associated costs and liability are also tough pills for corporations to swallow.

Although on-site child care centers seem to be in the minority of active corporate child care programs now, that is changing, at least within some industries. "There's been an incredible increase in the number of corporations providing on-site child care," notes Kaye Krebs, national marketing director for Kinder-Care at Work. She says the number of such centers has skyrocketed by 400% in the past three years. "We all realize that this is the child care solution of the future; it is where all major corporations are going."

A case in point is an on-site child care center currently being built as part of a $4.1 million, 40,000-sq-ft employee center at the Houston headquarters of Brown & Root, an engineering and construction firm that counts the chemical industry among its prized clientele.

Chemical companies eventually may warm up to the idea of on-site centers. But for now, some companies are addressing their employees' child care center demands—while being sheltered from excessive cost and liability—by supporting community near-site centers. For example, Dow and its sister company, Dow Corning, are working with representatives of Midland area employers and Bay City Public Schools to design a pilot, 24-hour child care center for the community, which is slated to open late this month. Dow Chemical's initial contribution to the center was $85,000; Dow Corning put in $50,000, with additional funding coming from other neighboring businesses.

Dow's Mischley says the center should help solve child care problems for shift workers who often have to work during hours when day care centers typically are closed. She says Dow's philosophy is to take a community approach to solving child care dilemmas; it tries to help nurture these programs by contributing leadership and supportive monies.

Corporate child care options, however, go beyond on-site or near-site centers. Dependent care spending accounts seem to be the most widely adopted program, possibly because this program requires little financial support from the corporation. This benefit option allows employees to put aside up to a federally set cap of $5000 per year of their pretaxable income to defray child care expenses. For most parents, this seems to be a realistic ceiling. Air Products, for example, learned from a survey of employees that the average annual cost of child care was $3700.

One of the drawbacks of this benefit is that employees are penalized for not exactly estimating the amount to put into the account. They lose what they don't use and they have to pay taxes on any amount they spend on child care beyond what they set aside in the account. Another disadvantage is that parents must dole out the money first and then be reimbursed. Dow began offering this benefit in 1987, but Mischley notes that it does not have a very high utilization rate; less than 4% of the company's employees at some locations take advantage of it.

To ease the employee cash flow problems with flexible spending accounts, some companies have adopted voucher programs, notes Carol Sladek, a consultant for Hewitt. Under these programs employees are issued coupons worth a certain amount of money for child care. "This is a new arrangement and I think we will see more companies adopting this program once companies have got the bugs worked out," says Sladek.

Another popular and fast growing benefit program that many companies are providing is access to resource and referral (R&R) services. Under these programs a corporation will typically contract with an outside service organization specializing in locating child care tailored to each employee's needs. These firms help employees locate convenient centers or help them advertise and interview for nannies, for example. At many companies, including Air Products, the service is 100% at the expense of the employer.

Many companies are adding sick child care programs to their roster of expanded services. They recognize that even employees with perfectly adequate day-care arrangements often get stuck when their kids get mildly sick. Many day-care centers will not accept sick children. In one move, a few years ago, Du Pont gave $40,000 to a group of day-care professionals to build Sniffles & Sneezes, a sick child care center that is open to the Wilmington community.

Another progressive benefit some companies offer is overnight/overtime dependent care. For example, Tenneco Gas has a plan that reimburses some employees for dependent care expenses resulting from overnight business travel or a company-required overtime assignment.

Companies are also becoming more generous with their family leave policies. Most companies provide fully paid time off for child birth, with the length of leave based on the physician's recommendation—usually six weeks. Dow's family leave policy allows employees up to 12 weeks of employment-protected, unpaid leave for parents of newborn or newly adopted children.

Just this month, Dow implemented a rare policy that provides a $3000 reimbursement to an employee to help defray the cost of legal adoption. Under the plan, an employee also may take up to four weeks of paid leave if there is no other parent in the home to act as the primary care giver. Some adoption agencies require that a new parent provide the initial care to the adopted child for a set period of time, notes Mischley. This time helps them do that or it can be used to travel to another country and pick up an adopted child, for example.

Air Products employee picks up daughter from child care at end of day

To help employees better juggle their family and on-the-job responsibilities, many companies are now offering flexible work arrangements. This flexibility can make it easier to care for children or to work out other personal needs. These arrangements might include part-time work, job-sharing, or telecommuting, where employees work from home or from satellite offices, often connected to the main office by computer. This type of flexibility is something chemical company employees—women and men—say they want. For example, a recent Du Pont survey of their employees at three sites across the country (70% were men) showed that 56% were interested in flexible work schedules, compared with 37% five years ago. In response, Du Pont has developed comprehensive, flexible work practice guidelines and is experimenting with many pilot programs.

But old habits die hard. While many chemical companies are adopting these work and family programs, they are not easily accepted corporatewide. "We've got top management support and grass-roots desire for these programs. The place where our organization requires the most development is in middle management," says Pierce. "Usually, once these managers are educated on how the issues impact their employees, most tend to come around." Communication and success of pilot programs will help sell the concepts, say companies.

Cost is an obvious drawback to offering these work and family programs. But Sladek notes that child care assistance can be relatively inexpensive compared with health care and retirement benefits, for example. "So employers get a larger bang for their buck."

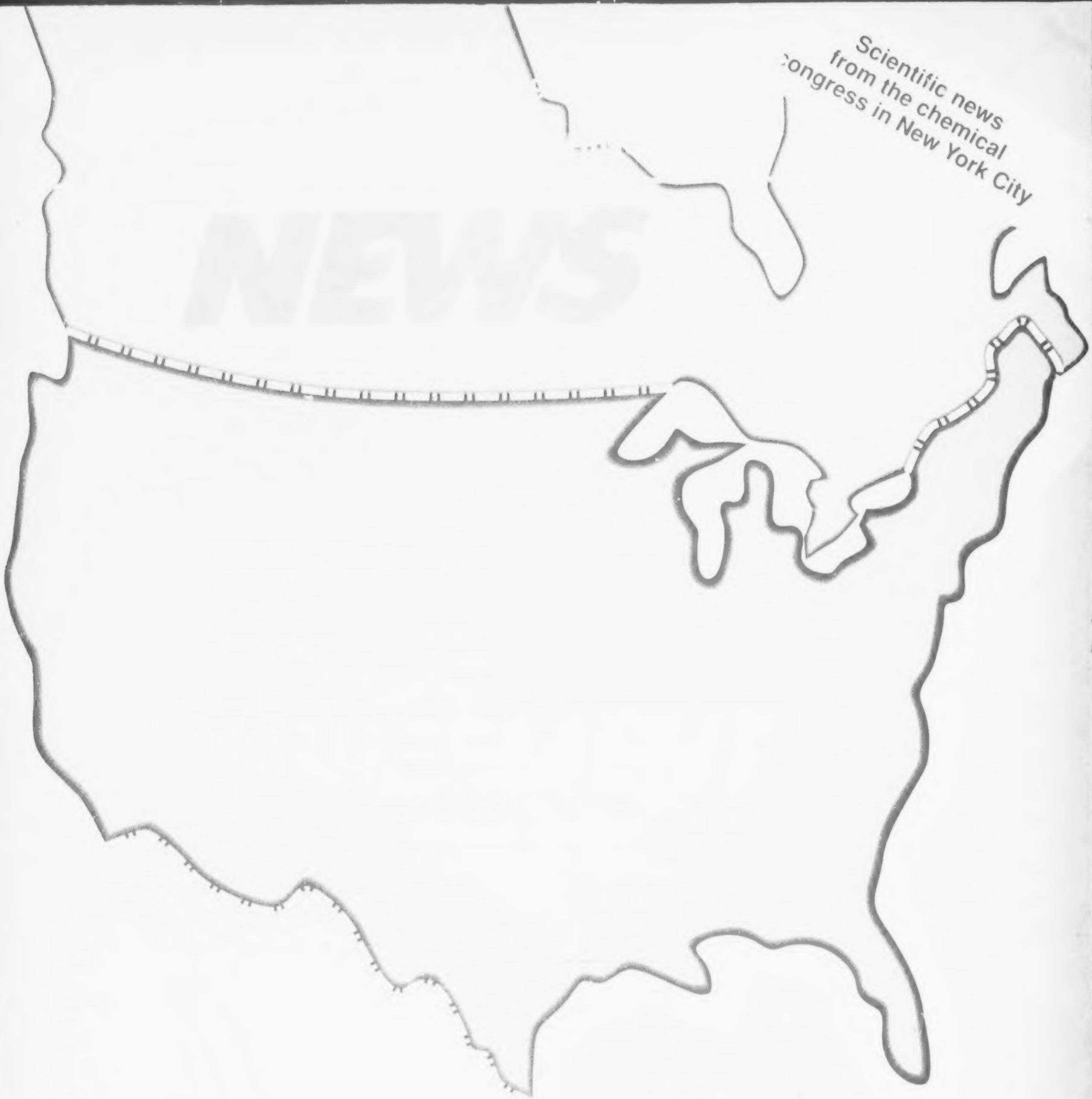
Indeed, many companies with these benefits are starting to detect a favorable return on investment, according to Catalyst, a New York City-based women's research group, which recently did a study of flexible work arrangements. In interviews with more than 150 employees as well as their managers in diverse industries, Catalyst notes 68% of respondents said flexible work arrangements had affected retention positively. For 58% of respondents, flexible work arrangements have had a positive effect on recruitment or are projected to have a positive effect in the future. Almost two thirds reported that employees who utilize flexible work arrangements were more productive. And 70% of respondents reported that flexible work arrangements had a positive effect on morale.

Interestingly, these benefits programs will likely help companies recruit and retain both women and men. The Du Pont survey of 8500 of its employees, which polled the preferences of men, showed that 40% had considered another employer that offered more job flexibility, up from 25% three years ago.

"Clearly, we have a more productive work force," says Handwerk. She notes that Air Products' child care programs have probably made life easier for the 68% of its employees that reported difficulty in finding care. That means there has been less absenteeism and less time spent away from work looking for satisfactory child care resources, she reasons. "There's also a higher rate of satisfaction in terms of a parent knowing his or her child is in the right kind of care relative to what the employee wants."

"More and more, as the work force composition continues to change and new and different types of employees come into the chemical industry, more companies are going [to view providing work and family benefits] as a very critical bottom line business issue," says Handwerk. "To remain competitive, you've got to have high-quality products and services, but you've also got to have the human resources that are going to drive your corporation. And without these kinds of benefits programs, this kind of innovation, you're simply not going to be competitive." □

NEWS



Scientific news
from the chemical
congress in New York City

Volume 69, Number 36
CENEAR 69 (36) 1–60
ISSN 0009-2347

CHEMICAL & ENGINEERING NEWS

SEPTEMBER 9, 1991

News of the Week

- **Conference will convene this week in Geneva to review and strengthen the 1972 Biological Weapons Convention, which calls for wholesale banning of such arms.** Page 4
- **Research satellite to study ozone, trace gases in the upper atmosphere is slated to be launched this week aboard NASA's space shuttle *Discovery*.** Page 5
- **Cooperative agreement between Chemical Abstracts Service and Molecular Design will enable scientists to use a single system to access both in-house and public databases.** Page 5
- **Chemical Abstracts Service director Ronald L. Wigington has been moved to a newly created post, and Clayton F. Callis, who is retired from Monsanto, will serve as interim director until a permanent replacement is found.** Page 6
- **FDA committee has recommended approval for Centocor's monoclonal antibody for battling sepsis, but has delayed action on a similar product developed by Xoma.** Page 6

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Business

First-half 1991 revenues up for most biotechnology firms despite almost all registering a drop in profits. **Page 17**

Government

From the New York chemical congress: OSHA's and EPA's regulatory responsibilities overlap, leading to a sometimes uncomfortable cooperation; Canadian, Mexican, and U.S. efforts to abate pollution discussed at symposium on environmental progress. **Page 21**

Science/Technology

From the New York chemical congress: Pressure to commercialize safe and effective chlorofluorocarbon substitutes is challenging chemical industry; thermochemical method classifies solid acids and bases; long-term predictions for pesticide market are mixed. In other news, report on catalysis in Belgium calls for multipronged approach to furthering education, training, and research in catalysis. **Page 27**

Education

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ACS News

Candid photos from the chemical congress give a glimpse of the plethora of activities and events in New York. **Page 42**

News Focus

Mexico's chemical industry is readying itself for a possible North American Free Trade Agreement but faces some tough problems, especially the reins on investment, lack of integration in the petrochemical sector. Page 7

Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
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Subscription Rates 1991: Printed editions: nonmembers U.S. 1 yr. $95, 2 yr. $171; outside U.S. 1 yr. $131, 2 yr. $243. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $12. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Universal symbol for chemicals

In conjunction with efforts in planning a chemical-related workshop, the workshop committee couldn't find an acceptable symbol for chemicals that could be used in a workshop logo. It became uncomfortably clear to us that there was not a universally recognized symbol for chemicals. This is quite startling in as much as the nine-member committee, consisting of professional chemists, was unable to identify such a symbol.

In view of the number of practicing chemists and the importance and common place of chemicals in our everyday life, I've concluded there is a need for a universally recognized chemical symbol. I wonder if other ACS members have been confronted with this issue, and if it isn't an issue of sufficient importance and breadth that ACS should look into the matter further and possibly try to develop a chemical symbol that would become recognized and/or associated with chemicals by one and all.

John L. Cox
Staff Scientist, Chemical Process
Development Section
Battelle Pacific Northwest Labs
Richland, Wash.

Project SEED

The letters responding to my Comment (C&EN, March 28, page 65) are greatly appreciated. Keith Symcox (C&EN, May 20, page 3) wondered if his difficulties in recruiting busy university faculty members to provide research opportunities for his high-ability students from low-income families are unique to metropolitan Oklahoma City. I can assure him that he is not alone.

Managing a high school student in a laboratory research project is not trivial. Even though Project SEED students are required to have completed a high school chemistry course so that they have at least minimal competence in the handling of chemicals, a successful project must be extremely focused and the preceptor must be prepared to help the student leapfrog to a conceptual grasp of its goal. Not everyone has the organizational and teaching ability required, and not all who do also have a strong desire to help young people from less fortunate circumstances. We hope that ACS members with the interest and ability to motivate these deserving high school students will respond in increasing numbers as the number of children living in poverty continues to grow.

Don Kennedy (C&EN, May 20, page 41) is among those for whom I did not make a couple of points sufficiently clear. First, when Erich Bloch compared Project SEED to a drop in the bucket, he was not referring to its financial support. Project SEED draws funds from many sources: donations from members, corporations, universities, ACS local sections and divisions, as well as federal funds from the National Science Foundation, the Department of Energy, and the Department of Labor. Kennedy raises the important point that programs that request funds must be accountable, and Project SEED enjoys a solid reputation as being exceptionally cost-effective [*Science*, **231**, 1053, (1986)].

Second, Project SEED is not a minority-focused program, although approximately half of all SEED students come from minority groups that are underrepresented in the scientific work force. However, since the science training pipeline contains relatively few children from families living in poverty, Project SEED's entire target population can be correctly seen as an underrepresented group in science.

Kennedy and other ACS members are the owners of Project SEED. It is important that members' pride of ownership of this worthwhile program continues to be expressed in terms of their support and participation as preceptors or contributors.

Edwin T. Harper
Indiana University School of Medicine
Indianapolis

Dangerous use of nylon resin

A rack for transporting lumber along the side of an automobile is pictured in your article on plastics (C&EN, June 10, page 39). This rack, which appears to project

Correction

- July 22, page 3: In the letter on boric acid, the Encyclopaedia Britannica reference should be 14th edition, not 4th edition.

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Mexico's Chemical Industry Gears Up for North American Free Trade

But government rules for both foreign and private investment and lack of integration in the petrochemical sector make chemicals a politically sensitive issue

Earl V. Anderson, C&EN Northeast News Bureau

Negotiations that could lead to a North American Free Trade Agreement (NAFTA) among Canada, Mexico, and the U.S. are under way. Industries of the three countries are jockeying for position to influence their country's negotiating strategy and goals.

Nowhere is this more true than in the chemical industry. In all three countries, the chemical industry has well-organized groups advising their respective governments on various aspects of NAFTA.

There are many NAFTA issues on which the chemical industries of the three countries probably can agree—but not on all.

In many respects, what the U.S. chemical industry wants out of a trade agreement is different than what the chemical industry of Canada wants, which differs with what Mexico's chemical industry wants. In this first of a series of articles, C&EN examines NAFTA from the Mexican chemical industry's point of view. Future articles will examine NAFTA from the Canadian and the U.S. points of view.

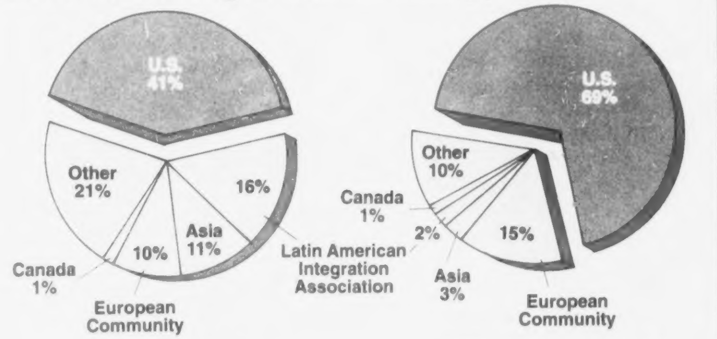
Mexico is a developing country, but it's edging ever closer to industrialized status, says one Mexican economist. "Whether it wants to or not, Mexico will be part of the First World," says Jaime Serra Puche, Mexico's Yale-educated Secretary of Commerce & Industrial Development.

Actually, Mexico started heading in that direction in 1986. After pinning its economic hopes on the 1970s' oil boom, Mexico watched its economy collapse in 1982 along with world oil prices. Miguel de la Madrid Hurtado, then President of Mexico, started dismantling protectionist barriers that shielded inefficient Mexican industries and began opening up the windows of the Mexican economy to the fresh air of free-market competition.

He took a giant step in 1986, when he led Mexico into the General Agreement on Tariffs & Trade (GATT). Now his successor, Carlos Salinas de Gortari, is taking another giant step. He is leading Mexico into a possible North American Free Trade Agreement with the U.S., its elephantine neighbor to the north, and with Canada. The implications are enormous for Mexican industries. Its chemical industry is no exception.

Ever since government officials of the three countries became serious about negotiating NAFTA, chemicals—and particularly petrochemicals—have emerged as a "sensitive political issue." Few company officials, and even fewer government officials, agree to talk about it openly. Those who do choose their words carefully.

U.S. is Mexico's largest chemical trading partner



1990 Mexican chemical exports = $1.88 billion

1990 Mexican chemical imports = $2.65 billion

Source: ANIQ (Asociación Nacional de la Industria Química)

Getting legislative approval for NAFTA in Mexico

Like the U.S. Congress, the Mexican Congress will play a big role in approving and implementing any North American Free Trade Agreement (NAFTA). But the way the Mexican legislature goes about it will be much different.

For instance, the "fast-track" procedures in the U.S. mean that Congress must vote a trade agreement "up or down," with no amendments (C&EN, June 3, page 6). In Mexico, only the Senate approves a trade agreement. And it can make changes. The lower house, or Chamber of Deputies, cannot approve or disapprove a trade agreement. However, the Chamber will make its weight felt in shaping the implementing legislation. And some types of legislation must go through the Chamber before they reach the Senate.

In Mexico, a trade agreement such as NAFTA is legally an international treaty. Mexican constitutional provisions regarding international treaties would apply to NAFTA. The Mexican constitution gives President Carlos Salinas de Gortari the power to start, negotiate, and conclude international treaties. But, when agreement is reached, the deal has to be approved by the Mexican Senate, then ratified by the President and published in the Diario Oficial de la Federación, Mexico's counterpart to the U.S. *Federal Register*.

If the Mexican Senate makes any changes in the NAFTA accord, which is unlikely, the President will have to notify the U.S. and Canada of these changes. If the Senate votes down the agreement, which also is unlikely, the President will not be able to ratify it. If this does happen, though, it will not become law in Mexico, and the Mexican President will have to notify his trading partners of this turn of events.

However, once the Senate approves the agreement, with or without changes, it no longer has jurisdiction over it. The President then is free to ratify the agreement and to administer it. In addition, he has the power to terminate the agreement.

To comply with the terms of a NAFTA, Mexico may have to pass new legislation or amend existing laws. That's the job of both the Senate and the Chamber of Deputies. Senators, Deputies, or the President may introduce new bills. This legislation must be approved by a majority vote in both houses. Then it must be approved by the President and published in the official bulletin. If the President doesn't send a bill back to the originating body within 10 working days after receiving it, the bills are considered approved.

In the past, a rule of thumb in Mexico was that, if the President wanted it, the Senate and the Chamber would oblige. Although this is still more true in Mexico than in the U.S., NAFTA may very well run into some opposition in the Mexican legislature, particularly in the Chamber. Still, NAFTA probably will be approved in Mexico.

In June, the Chemical Manufacturers Association (CMA) released a series of position papers on NAFTA (C&EN, June 24, page 9). Its counterpart in Mexico, ANIQ (Asociación Nacional de la Industria Química) has completed its NAFTA position papers. But unlike CMA, it is keeping them secret.

Why this "political sensitivity?" The answer lies in Mexico, where that country's constitution and various laws have divided the petrochemical industry into two camps. One is the public sector, embodied in the government-owned oil monopoly, Petróleos Mexicanos (Pemex).

By law, production of all "primary," or basic, petrochemicals is reserved for Pemex. They are off-limits to private companies—domestic or foreign.

Private companies can produce all other petrochemicals that are not on the "primary" list. But, says Benito Bucay, "the fact is that we are talking of two [petrochemical] industries in Mexico." Bucay, who is assistant director of the Mexican firm Grupo Desc and a recognized leader in the Mexican chemical industry, adds that these two industries, no matter how closely they cooperate with each other, are in a difficult position to face fully integrated world competitors.

In the Mexican chemical industry, "integration" has become a buzzword. The lack of integration, from basic petrochemical feedstocks to downstream products, is one of the major factors coloring the Mexican chemical industy's approach to the NAFTA negotiations. The other is investment.

Because primary chemicals are off-limits to private investment, Pemex has to go it alone to raise capital for much needed new capacity in basic petrochemicals. But it has had trouble finding that capital.

According to Mexico's Petrochemical Commission, Pemex will need $1.7 billion between 1991 and 1995 to build the primary petrochemical capacity needed to meet demand. The secondary petrochemical industry must find an additional $1.5 billion.

The logical source for this capital is foreign investment. But neither foreign nor domestic companies can invest in the primary petrochemical sector. And foreign investment is limited to 40% in the secondary petrochemical sector. (There is now a "tertiary," or unregulated, petrochemical sector in Mexico, in which foreign companies can own 100% of a plant.)

This has led to a Catch-22 type situation. Without loosening the rules on foreign investment in general and, in particular on private investment in basic petrochemicals, Mexico won't have the money to build the capacity it needs. Hence, the integration that Mexico's petrochemical industry so sorely needs to become more efficient and more competitive in an increasingly open domestic petrochemical market, as well as in other world markets, will remain out of reach.

But Pemex's oil—and by extension its basic petrochemicals—are an emotional nationalistic symbol for Mexicans. Ever since Lázaro Cárdenas, one of Mexico's most revered presidents, nationalized the oil industry in 1938, Mexicans have been and still are very proud of the country's ownership of its oil resources. And the country's constitution guarantees that ownership.

To change the constitution that established this monopoly would be politically and socially dangerous. U.S. trade officials say they understand this. And Mexico's political leaders have told their people that oil will not be part of the NAFTA negotiations. But many Mexican nationalists still are convinced that NAFTA is just another attempt by U.S. companies to regain control of Mexican oil.

Several times since the start of the NAFTA negotiations, rumors have cropped up that the energy sector, including petrochemicals, would be part of the negotiations. Such rumors have consistently been denied by top Mexican officials. At NAFTA's ministerial meeting last month in Seattle, Wash., Mexico's Serra said that negotiations on energy and petrochemicals "will be totally respectful of the constitutional restrictions of Mexico."

Earlier this year, however, Serra made a distinction between primary petrochemicals, which are protected by article 27 of the Mexican constitution, and secondary petrochemicals, which are not. Secondary petrochemicals, accounting for 80% of Mexican petrochemical output, will be on the NAFTA negotiating table, he said.

As far as basic petrochemicals are concerned, there are ways to change the situation in Mexico without tampering with the constitution. Various laws and decrees have liberalized some aspects of basic petrochemicals in Mexico. In the past five years, many products that once were classified as primary petrochemicals have been reclassified as secondary products, making them accessible to private investment.

In 1986, Mexico switched 36 petrochemicals from its primary list to its secondary list. In 1989, it cut the list of primary petrochemicals reserved for Pemex from 67 to only 20 products. Since then, methyl *tert*-butyl ether (MTBE), the ever more popular gasoline additive, has been taken off the primary list. It now stands at 19.

With the addition of MTBE, there now are 67 products on the secondary petrochemical list. Private companies, as well as Pemex, can produce these products. And foreign investment up to 40% is allowed. In the tertiary, or unregulated sector, foreign investment can run up to 100%. Even in secondary petrochemicals, foreign companies can own more than the legal 40% maximum through a financial sleight of hand known as investment trusts.

Changing the classification of primary petrochemicals to secondary petrochemicals had one major goal: to lure more private investment into critical petrochemicals that previously had been off-limits and that Pemex had trouble supplying. The move was only partially successful in attracting private investment, particularly foreign investment. Private Mexican companies say Pemex still can't meet their demand for all of the products that Pemex alone makes in Mexico. Pemex, however, claims that it is fulfilling 90% of Mexico's demand for its products.

Recently, Pemex came up with what it calls novel financing schemes to attract the private capital—domestic and foreign—that it needs to complete two petrochemical plants and to start some others. But so far the amounts involved have been small.

With an eye on the need for a much greater degree of integration in Mexico's petrochemical industry and the foreign investment required to achieve it, one expert observer of the Mexican chemical scene says that, as far as chemicals are concerned, the free-trade negotiations will not be so much "trade" talks, as they will be "investment" talks. That undoubtedly is an oversimplification, but there's a huge element of truth in this statement.

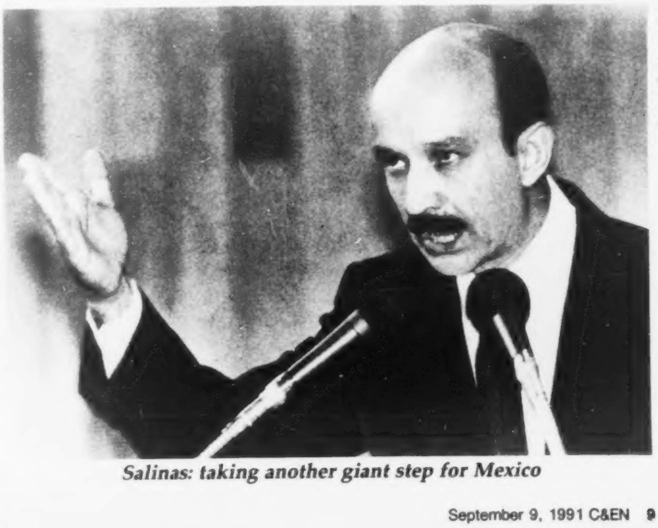
Certainly U.S. multinational chemical companies, a likely source of much of the foreign investment needed by Mexico's chemical industry, want access to Mexico's primary petrochemical sector—and more access than they now have to the secondary petrochemical sector. The Mexican chemical industry realizes that it needs this source of capital to finance the additional capacity that it needs and to promote further integration within the industry. But these wants and needs run smack into Mexico's constitution and national pride.

Little wonder, then, that petrochemicals have emerged as a politically sensitive issue in NAFTA negotiations. But for Mexico's chemical industry, NAFTA negotiations will be a lot more than petrochemical integration and investment. The industry's "statements of principles," or policy papers, reportedly cover no less than 18 different issues.

Actually, these policy statements are not ANIQ's, but were developed by the chemical industry committee that is advising Mexico's negotiating team. As in the U.S., Mexico has developed a series of public-sector advisory committees and, like in the U.S., these committees are loaded with acronyms.

The chemical industry advisory group in Mexico is Comité de Industria Química (CIQ). It is similar to ISAC 3, the industry sector advisory committee on chemicals in the U.S. Similar, but not exactly the same.

Leopoldo Rodríguez, who heads CIQ, says that his



Reuters/Bettmann photo

Salinas: taking another giant step for Mexico group is a combination of a U.S. ISAC and the international trade committee of a trade association such as CMA, with a touch of the U.S.'s OCITA (Office of the Chemical Industry Trade Adviser) thrown in. The umbrella organization for all of Mexico's public- sector advisory groups is COECE—Coordinadora de Organizaciones Empresariales de Comercio Exterior. It, in turn, has formed a special working group, Coordinación Empresarial para el Acuerdo de Libre Comercio (CEALC), that focuses on NAFTA.

In Mexico, a host of confederations, associations, chambers, and councils look after the interests of various industrial sectors. More than a dozen of these national business groups make up COECE's membership. CIQ works closely with one of them—CANACINTRA, the Spanish acronym for the National Chamber of the Manufacturing Industry. In the other direction, it also works closely with the many trade associations of various sectors of the chemical industry, such as paints, inks, and plastics.

Rodríguez, who also is assistant director of the firm Industrias Resistol, says there is a "peculiar" reason why the chemical industry's position papers have not been made public. The Mexican chemical industry, he explains, is one of the few industries that understood from the start that NAFTA would be an "issues" negotiation and not a "product-by-product" negotiation.

Based on their experience in past trade negotiations, particularly within Latin America, Mexican industries became accustomed to product-by-product negotiations. The Latin American Integration Association, known by its Spanish acronym ALADI, is but one example of such negotiations.

Rodríguez explains that, because of this, COECE officials believed that early publication of the chemical industry's "issues-oriented" position papers might be detrimental to the interests of other Mexican industries. Thus the delay in making them public.

But he emphasizes that the chemical industry has no interest in keeping the position papers secret. It's not clear, however, exactly when they will be made public. Presumably, that should have happened by now. Rodríguez also stresses that Mexico's chemical industry wants to develop as many joint policy statements as possible with CMA in the U.S. and with the Canadian Chemical Producers Association (CCPA). Mexico's ANIQ already has produced two such statements with CMA. One supports "fast-track" legislation in the U.S. Congress (C&EN, June 3, page 6). The other recommends negotiating environmental issues parallel to, but not a part of, the NAFTA negotiations. ANIQ has issued no joint policy statements with Canada's CCPA yet. But that's primarily because Canada was a late starter in the NAFTA preliminaries.

Only 19 products remain on list of primary petrochemicals only Pemex can produce

Ammonia
Benzene
Butadiene
Dodecylbenzene[a]
Ethylene
Heptane
Hexane
Methanol
n-Paraffins
Pentanes
Propylene
Propylene tetramer
Raw material for carbon black
tert-Amyl methyl ether
Toluene
Xylenes
o-Xylene
p-Xylene

[a] From propylene tetramer. **Source:** ANIQ (Asociación Nacional de la Industria Química)

There are many NAFTA issues upon which the chemical industries of the three countries can probably agree. There are some, no doubt, upon which they probably cannot. Rodríguez won't distinguish between the two.

But secrecy or no secrecy, some things are certain. One is that Mexico's chemical industry is an ardent NAFTA supporter. It sees NAFTA as a gateway to the world's largest single chemical market. It also believes that NAFTA affords the best opportunity to eliminate existing trade barriers to that market and to prevent future barriers from being erected.

Antonio Juarez Alvarado, petrochemical coordinator for Pemex's newly autonomous petrochemical division, says from a petrochemical point of view, Pemex "basically supports NAFTA." And, he adds, "we are not as apprehensive (about NAFTA) as the secondary petrochemical sector." But Eduardo Flores Magón, technical secretary of Mexico's Petrochemical Commission, says about 90 to 95% of companies in the secondary petrochemical industry favor the NAFTA negotiations.

Lars R. Christianson is very happy about NAFTA. Christianson, head of a small Mexican chemical company that bears his name, negotiated a lot of write-offs, shed the company's commodity products, and restructured the firm to concentrate on specialties, such as ethoxylates. With many U.S. and European companies interested in coming to Mexico, "we are the pretty girl at the party," says Christianson. His company is a strong acquisition candidate and he would be happy to have it acquired—"up to 50%."

Federico Ortiz Álvarez, director of Celanese Mexicana, says globalization of the world's economies and Mexico's new "open-market" approach "makes us actors in this process of change, whether we like it or not." And he believes that a free-trade agreement with the U.S. is the best alternative for guaranteeing the continued growth of the Mexican chemical industry, especially its exports.

The U.S. already is a good customer for Mexican chemicals—in fact, it's the largest single chemical export market by far. And the U.S. supplies most of Mexico's chemical imports.

Last year, the U.S. imported $665 million in chemicals from Mexico, according to U.S. Bureau of Census data. Using Mexican preliminary data, the figure is $772 million. The U.S. shipped $2.3 billion worth of chemicals to Mexico in 1990, according to U.S. data (Mexican data say $1.8 billion). But by any yardstick, Mexico is running a large chemical trade deficit with the U.S.

U.S. chemical production dwarfs Mexico's . . .

Top 50 rank[a]		1990		1989		% change 1989-90	
		Mexico	U.S.	Mexico	U.S.	Mexico	U.S.
		(thousands of metric tons)					
1	Sulfuric acid	3974	40,171	4026	39,282	−1.3%	2.3%
4	Ethylene	1370	17,001	1188	15,853	15.3	7.2
6	Ammonia	2632	15,386	2555	14,842	3.0	3.6
7	Phosphoric acid	na	11,045	677	10,646	na	3.7
8	Sodium hydroxide	429	10,605	428	9,517	0.2	11.4
9	Propylene	366	10,034	295	9,176	24.1	9.3
10	Chlorine	387	9,925	382	10,356	1.3	−4.1
11	Sodium carbonate	448	9,004	456	8,995	−1.8	0.1
12	Urea	na	7,171	512	7,226	na	−0.7
13	Nitric acid	na	7,031	310	7,575	na	−7.2
14	Ammonium nitrate	na	6,446	106	7,140	na	−9.7
15	Ethylene dichloride	394	6,033	357	6,205	10.4	−2.7
16	Benzene	320	5,380	291	5,294	10.0	1.6
18	Vinyl chloride	231	4,831	194	4,364	19.1	10.8
19	Ethylbenzene	192	4,078	149	4,182	28.9	−2.5
20	Styrene	158	3,638	120	3,688	31.7	−1.4
21	Methanol	210	3,624	208	3,239	1.0	11.9
22	Terephthalic acid	279	3,488	276	3,769	1.1	−7.4
23	Formaldehyde	na	2,908	112	2,889	na	0.7
25	Toluene	368	2,767	344	2,649	7.0	4.5
26	Xylene	404	2,586	391	2,631	3.3	−1.7
27	Ethylene oxide	265	2,531	208	2,413	27.4	4.9
28	*p*-Xylene	226	2,359	222	2,490	1.8	−5.3
30	Ammonium sulfate	na	2,263	390	2,127	na	6.3
31	Hydrochloric acid	na	2,123	282	2,880	na	−26.3
32	Cumene	53	1,955	50	2,059	6.0	−4.9
33	Acetic acid	144	1,706	132	1,737	9.1	−1.8
35	Phenol	36	1,592	34	1,765	5.9	−9.8
36	Propylene oxide	0	1,452	0	1,452	0	0
37	Butadiene	21	1,433	21	1,402	0	2.0
38	Acrylonitrile	122	1,374	85	1,184	43.5	16.1
39	Carbon black	125	1,302	118	1,320	5.9	−1.5
40	Vinyl acetate	51	1,157	53	1,120	−3.8	3.1
41	Cyclohexane	75	1,120	54	1,084	38.9	3.3
43	Acetone	55	1,007	56	1,134	−1.8	−11.1
47	Sodium sulfate	496	667	604	685	−17.9	−2.9
48	Isopropyl alcohol	19	626	18	649	5.6	−3.6
48	Caprolactam	71	626	62	594	14.5	5.2

. . . and the story is the same for plastics

Polyethylene, low density	348	5,071	340	4,400	2.4	15.3
Polyvinyl chloride[b]	292	4,123	288	3,847	1.3	7.2
Polyethylene, high density	176	3,778	97	3,674	81.0	2.9
Polystyrene	130	2,273	125	2,313	4.0	−1.8
Polypropylene	0	3,774	0	3,284	0	14.9

a Based on C&EN's Top 50, April 8, page 14. b Includes copolymers. na = not available. **Sources** (for Mexican data): Pemex, ANIQ (Asociación Nacional de la Industria Química)

Global chemical exports from Mexico hit almost $1.9 billion last year, up about 7% over 1989. More than 40% of that went to the U.S. Mexico's second largest chemical export market—ALADI—accounted for a distant 16% of Mexico's chemical exports. Only $10 million, a minuscule 0.5%, went to Canada.

The U.S. also supplied a lopsided 69% of all Mexican chemical imports, which totaled $2.6 billion in 1990. Canada, on the other hand, supplied less than 1% of Mexico's chemical imports. Mexico had a chemical trade deficit of just over $1 billion with the U.S. alone last year. But its overall chemical trade deficit was only $769 million. That's because it was able to run up large chemical trade surpluses with ALADI countries, Asia, and some other countries.

Mexican chemical leaders want to correct that chemical trade deficit, especially the lopsided deficit with the U.S. But other indicators paint the Mexican chemical industry as much less than equal to its large counterpart in the U.S. Chemical shipments in the U.S. last year were a hefty $285 billion. Mexican chemical sales, at about $13 billion, are only 5% as large. Average sales per worker in the U.S. chemical industry are $162,000. In Mexico, they're only $91,000. This elephant-mouse relationship reflects the tremendous competitive pressures that Mexico's chemical industry faces in an open-market environment. As a result, the industry is trying to be very realistic in analyzing the NAFTA negotiating process.

Mexico's chemical industry is understandably concerned about many issues that are certain to come up in the NAFTA talks. Investment ranks high on the list, but there are many others. Among them: tariffs, market access, intellectual property rights, rules of origin, dispute settlement procedures, and a host of others.

Rodríguez cautions that, although Mexico's chemical industry supports NAFTA, it must make certain that the "right things for our industry" are negotiated. Only if they are will the industry continue supporting the negotiations and their outcome.

Much, he says, depends upon finding some degree of what he calls "complementarity" between the Mexican chemical industry and those of the U.S. and Canada. This does not mean divvying up production among the three countries such that, for example, the U.S. produces all of the polyethylene, Canada all of the polyvinyl chloride, and Mexico all of the polypropylene for the NAFTA region. Such an arrangement, says Rodríguez, has not worked well in Latin America in the past. Nor are the Mexican chemical trade advisers thinking as simplistically as that. However, they can't go into detail publicly about what they are thinking, says Rodríguez.

But it is not too difficult to surmise what they are thinking. Mexico's petrochemical industry has two distinct characteristics: It has a shortage of basic petrochemicals; yet, it has a surplus of downstream products such as synthetic fibers, plastics, resins, and elastomers, which it exports. In the so-called secondary petrochemicals sector, as much as 25%—even 50%—of some products are exported. Much of it goes to the U.S.

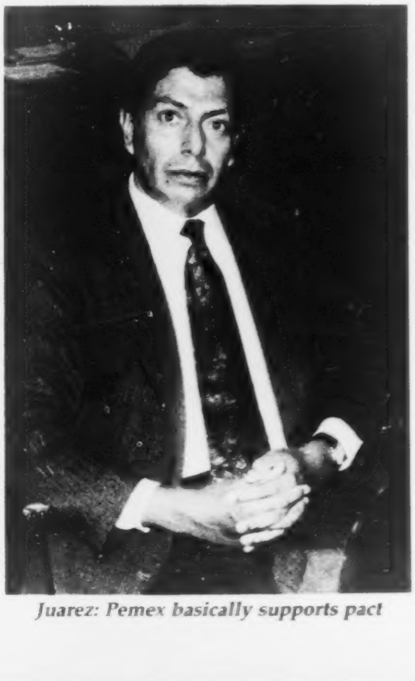
On the other hand, the Mexican chemical trade advisers see the U.S. petrochemical industry with a surplus in some basic products. This, coupled with a concentration of petrochemical plants running along the Gulf Coast from Baton Rouge, La., to the Isthmus of Tehuantepec, should leave ample room to find some degree of complementarity.

Tariffs, of course, are part of any trade negotiation, and NAFTA will be no exception. But, as a result of many multilateral negotiations held by GATT, most U.S. chemical tariffs already are low. Mexico lowered many of its tariffs when it joined GATT in 1986, but they generally are higher than those in the U.S.

Five years ago, Mexico's average tariff (not just chemicals) was about 40%. Now it's between 10 and 13%. In the U.S., the average tariff on Mexican products is less than 4%. But on some products, U.S. tariffs are exorbitantly high. Mexican shoes, for instance, are slapped with a 73% duty, and the duty on Mexican textiles is 37.5%.

About 42% of the $665 million worth of chemicals that the U.S. imported from Mexico last year entered the country duty free under the Generalized System of Preferences (GSP). For several chemical sectors, the percentage was well over 70%. Under the GSP program, the U.S. grants duty-free treatment to imports from qualified developing countries. Mexico is one of those countries. The U.S. chemical industry wants NAFTA to eliminate all chemical tariffs in stages over a period not to exceed five years, with longer staging for import-sensitive products. And, because it believes that the petrochemical industries of both countries have "similar levels of sophistication," it wants the staging schedules to be the same for both countries.

The Mexican chemical industry doesn't object to eliminating tariffs. But it's unlikely that the Mexican petrochemical industry buys the "similar level of sophistication" argument. Indeed, many of Mexico's industrial leaders, in and out of the chemical industry, want the NAFTA accord to specifically acknowledge their country's lower level of economic development. And they want Mexican industries to get a longer phase-in period for tariff reductions than U.S. industries do. Indeed, a transition period that is acceptable to all sides probably will be a key factor in the success of the negotiations.



Juarez: Pemex basically supports pact

If chemical tariffs were completely eliminated, GSP would be meaningless for Mexican chemical exports to the U.S. But until those tariffs are completely eliminated, GSP privileges will remain important to the Mexican chemical industry, and it probably will fight to retain them.

According to Rodríguez, the Mexican chemical industry's interest in tariffs goes well beyond chemicals. What it wants is to improve the competitiveness of domestically produced downstream products manufactured by companies that are the chemical industry's customers. Textiles are a good example. Mexican textiles face not only high tariffs in the U.S., but quotas as well.

"Our [tariff] concern is not narrow," says Rodríguez. "It encompasses the entire industrial chain." The reason is obvious. If its domestic customers are more competitive in regional and world markets, sales of the Mexican chemical industry rise.

In fact, the Mexican chemical industry would like to see downstream customers in all three NAFTA countries become more competitive against other world regions, such as Asia and Europe. "A rising tide will raise all ships," says Rodríguez.

While welcoming Mexico's drive to open its markets to foreign competition, many Mexican chemical companies are nevertheless worried about the increased competition they are getting from imports, particularly from the U.S. One chemical company official says, "What we used to call 'our' domestic market is not what it used to be as a result of imports." And he cites a "special situation" that is increasingly hurting his company and others like it.

His example: A U.S. chemical company has one customer with a 100 ton-per-month order and another with only a 10 ton-per-month order for the same product. Naturally, the larger customer gets a preferential—that is, lower—price. In Mexico, he says, there aren't many 100 ton-per-month customers, but there are many customers in the 10-ton category. These smaller customers are getting imports from the U.S. at the same price as the 100 ton-per-month customer in the U.S.

This, he says, is not dumping in the legal sense of the word. But he considers it unfair and hopes that the NAFTA talks can do something about it.

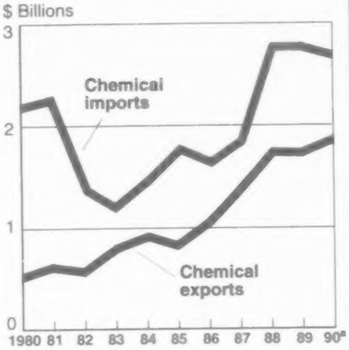
Another problem facing Mexican chemical companies stems from what he calls "the developing country system of standards" in Mexico. Downstream customers in Mexico import, at very low prices, products that would be considered substandard in the U.S. These imports compete with prime-grade products made in Mexico.

So why don't Mexican chemical companies make substandard products to meet the demand of their domestic customers? It's not that simple. No chemical company, U.S. or Mexican, makes substandard products on purpose. And, as this Mexican chemical executive points out, if only 3% of production in the U.S. is substandard, that's a lot. If 3% of Mexican production is substandard, it doesn't amount to much. This problem, he says, is common throughout the entire Mexican secondary petrochemical industry.

He also considers this type of import competition unfair, even if it may not be unfair in the legal sense. Either way, its impact is very real for many Mexican chemical companies. One solution, of course, is for Mexico to raise the standards that downstream Mexican customers must meet. The unspoken hope is that the NAFTA talks will provide the impetus to do just that.

Industrias Resistol's Rodríguez says that there are also situations in which import competition is fair, but still hurts many Mexican chemical companies. During Mexico's long romance with protectionism, for instance, Mexican chemical companies tried to achieve economies of scale by concentrating their product lines in a very few products. For example, 99% of Mexico's plasticizer requirements were met by dioctyl phthalate alone.

Mexican chemical exports have grown rapidly



a Preliminary. **Source:** ANIQ (Asociación Nacional de la Industria Química)

Many Mexican chemicals enter U.S. under Generalized System of Preferences

SITC No.[a]	Category	1990 U.S. chemical imports from Mexico ($ millions) Duty free[b]	Other	Total	% duty free
51	**Organics**	$ 93	$ 63	$157	59.2%
52	**Inorganics**	35	202	236	14.8
53	**Dyeing, tanning, and coloring materials**	16	23	39	41.0
54	**Medicinals and pharmaceuticals**	5	10	15	33.3
55	**Essential oils, toilet preparations, polishing materials**	34	11	44	77.3
56	**Fertilizers**	0	15	15	0
57	**Plastics in primary form**	23	8	31	74.2
58	**Plastics in nonprimary form**	56	20	76	73.7
59	**Other**	18	33	52	34.6
5	**TOTAL**	**$280**	**$385**	**$665**	**42.1%**

Note: Some totals may not add due to rounding. **a** Standard International Tariff Classification. **b** Under GSP (Generalized System of Preferences). **Source:** U.S. Bureau of the Census

Now that Mexico has opened its economy to foreign competition, these Mexican companies are finding it difficult to compete with the wide variety of products flowing into the country. Rodríguez says that the Mexican industry will have to diversify. But it won't be easy.

What can the trade talks do about such fair, but still tough, competition? Rodríguez emphasizes he does not want to see Mexico raise barriers to fair competition. But he hopes the trade negotiations will be able to increase awareness of what he calls "these gray areas," particularly when the competition comes from non-NAFTA countries.

Different chemical companies in Mexico have different pet peeves along with their high hopes about NAFTA. But no one fails to bemoan the lack of integration in the petrochemical industry and the private, especially foreign, investment needed to achieve it.

Eduardo Prieto, director of the Mexican firm Grupo Primex, says simply that Mexico's hydrocarbon resources are one of its major advantages. Its lack of petrochemical integration, he adds, is one of its major disadvantages. Fernando Sada of Celulosa y Derivados S.A. (Cydsa), noting the high degree of integration in the U.S. petrochemical industry, says the distinction between the private sector and government-owned Pemex prevents that kind of integration in Mexico.

Tomás Rodríguez of Celanese Mexicana says that integration is indispensable for Mexico's petrochemical industry. And he lists what could happen if the industry doesn't achieve it:

- Industry growth will be limited.
- It will continue to depend on imports.
- Its trade balance will be adversely affected.
- The entire Mexican economy will be adversely affected.
- Inflation will result from higher import prices.
- Export capacity will be limited.
- It will not be able to develop higher value-added products.

Celanese Mexicana's Ortiz concedes that some attempts have been made in the past to bring Pemex and the private secondary sector closer together. But, he adds, these attempts haven't achieved enough. "We should not speak of a public sector and a private sector," says Ortiz. "We have to think and act as a single, integrated sector—as one national petrochemical industry."

He cites Pemex's new petrochemical division, an autonomous unit operating separately from Pemex's much larger and domineering oil interests, as a "significant step" in the right direction. Not only have the dialogue and cooperation between the two sectors improved since the new division was formed, says Ortiz, but the division has been able to come up with novel financing schemes—ways for Pemex to attract the private investment it needs to bring on stream some of the much-needed new primary petrochemical capacity.

In Mexico's petrochemical industry, it is virtually impossible to separate the word "investment" from the word "integration." Investment in Pemex's primary, or basic, petrochemicals is the key to new investment in the entire petrochemical industry. Pemex's basic petrochemicals are the raw materials for the secondary petrochemical sector. And those raw materials are a prerequisite for investment, not only in secondary petrochemicals, but in sectors further downstream.

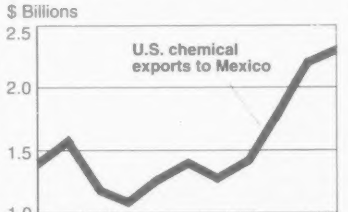
"We have a serious financial problem," admits Pemex petrochemical coordinator Juarez. To entice private sources, including foreign companies, into supplying some of the $1.5 billion it needs to complete planned projects, Pemex is experimenting with what he also calls novel financing schemes. These schemes allow private capital to flow into the primary petrochemical sector without violating the constitution.

Pemex already has used this approach to finish two plants at its Morelos petrochemical complex. It used about $10 million from Cydsa to finish an acrylonitrile plant. This same approach was used to complete the Morelos acetaldehyde plant, with $15 million coming from Celanese Mexicana. Both companies will be paid back with product from the new units.

Whether these methods will work for some of Pemex's larger proposed projects remains to be seen. Pemex detractors say they won't work for proposed projects that require huge chunks of capital. Among them: $600 million for an aromatics complex, $450 million for a new ethylene plant, and perhaps $350 million for MTBE capacity.

But Pemex apparently isn't discouraged by its detractors. Reportedly, French and German companies are interested in building—and financing—at least some of these major petrochemical projects. Their return on investment would come from renting the units back to Pemex for a specified number of years. After that time, Pemex would become the owner of the units.

U.S. runs huge chemical trade surplus with Mexico



Source: U.S. Bureau of the Census

The aromatics complex, which Pemex plans to build at its Cadereyta refinery, will be huge. Juarez says that the complex probably will include a 140,000 metric ton-per-year benzene unit, as well as plants to produce 400,000 metric tons of *p*-xylene, 18,500 metric tons of toluene, 54,000 metric tons of mixed xylenes, and 41,000 metric tons of *o*-xylene, along with all of the auxiliary units that accompany an aromatics complex of that size.

Pemex also plans to build another ethylene plant. This one will be built in the state of Tabasco and will have a capacity of 500,000 metric tons annually. It also is looking at several options for MTBE. The company may opt for one large MTBE plant or build several smaller units.

But first, says Juarez, Pemex wants to finish its much-delayed propylene plant at Morelos. Earlier this year, the company came on stream with Mexico's first polypropylene plant, also located at Morelos. But Pemex needs additional propylene capacity to replace the propylene that it has been importing. The company hopes to have its Morelos propylene unit on stream by the end of next year.

No one, not even Pemex, knows how successful these investment approaches will be. If they fall short of what Pemex needs, it or the government will have to come up with new ways to attract private capital into the primary petrochemical sector.

One possibility: reclassify even more primary petrochemicals as secondary products. Industrias Resistol's Rodríguez doubts if this approach will succeed. "We have already done a lot of that, and it hasn't been good enough," he says. But some Mexican petrochemical experts advocate pushing Pemex's petrochemical role all the way back to naphtha. Private companies would take over the rest of the petrochemical chain, from naphtha cracking downward through the remainder of the petrochemical stream. This would open up more of Mexico's petrochemical industry to private, as well as foreign, investment. And it would help spur the integration that the industry wants so badly.

Referring to the structural changes that have engulfed the global petrochemical industry over the past few years, Nicolás Guitiérrez Montero, director of Grupo Novum's Quinonas Division, says, "We can't keep doing what we've been doing for decades." The process of change is too radical for that, he adds, and only "equally radical changes" will make the Mexican chemical industry competitive.

Perhaps what the Mexican chemical industry really is hoping for is that NAFTA will provide those radical changes or, at least, emerge as a stimulus for them. Virtually every government and business leader in Mexico concedes that Mexico needs foreign investment to sustain its recent economic growth.

But capital for foreign investment is scarce. Many developing countries are competing for it. Eastern European countries are just the most recent examples.

Mexico must compete for it, too. Chemical company president Christianson says that you can't talk about good investment without having a good economic climate. This good climate, he says, will come out of NAFTA.

Indeed, NAFTA may be the best guarantee that Mexico will ever have of obtaining its share of foreign investment. Properly executed, it would go a long way toward restoring foreign investors' confidence in the Mexican economy. ☐

Revenues Grow For Biotech Firms But Few Show Profitability

Promise of revenue growth based on product approvals led to surge in biotech stocks despite lack of profits in the first half of 1991

Ann M. Thayer,
C&EN Northeast News Bureau

The first half of 1991 started on an upbeat note for biotechnology companies. A few product approvals in late 1990 and early 1991—the first since mid-1989—started people thinking again about blockbuster products and the potential for soaring revenues. Biopharmaceutical firms were optimistic about prospects for Food & Drug Administration approvals, the stock market was bullish on biotechnology stocks, and stock offerings were plentiful. All this activity occurred, with biotechnology stocks out-performing the overall stock market, despite the limited profitability among biotechnology companies.

In general, stock prices rose throughout the first quarter. Buoyed by a product approval and favorable patent decision, Amgen's stock rose from about $60 per share to about $126 per share. Trading for about $160 per share, a 3-for-1 stock split takes effect this month. On the losing side of the patent battle, Genetics Institute's stock fell about 50% after having gained the same amount in the first quarter.

Other companies, such as Biogen, Centocor, Cetus, Chiron, Immunex, and Xoma had steady growtn in stock prices in the first quarter. Most such increases were tied to successful or anticipated product approvals. But for Cetus, an FDA advisory committee's refusal in 1990 to recommend approval of one of the firm's products meant the company's stock fell from over $22 to under $8.00 per share before prices rose in the first quarter of 1991 and remained near $1[illegible] per share. Stocks of Genentech, Repligen, Genzyme, and Synergen remained relatively constant over the first half of the year.

This same trend has prevailed for agricultural biotechnology stocks. The exception is Ecogen, which is the primary factor behind the rising ag biotech stock index. Ecogen's financial outlook blossomed with several strategic partnerships, an infusion of capital, and growth in revenues. Its stock bounced back from a low of about $1.75 per share at the beginning of the year to trade now at about $10 per share.

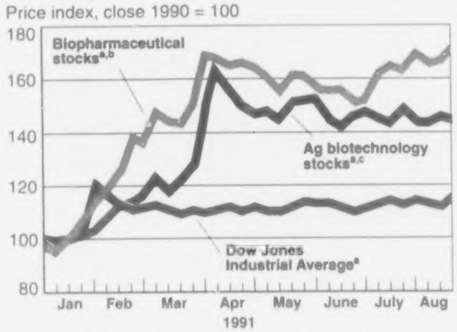
Before stock prices generally dropped slightly and then leveled off in the second quarter, companies were eager to raise capital through stock offerings. Many were extremely successful but, since then, the glut of offerings has led to others being canceled. A noteworthy initial public offering was held by Regeneron and brought in about $91 million, twice what was expected. Antisense company Isis Pharmaceuticals also went public and raised $36 million.

About the same time as its product was approved, Genzyme held a secondary offering that brought in $143 million. Synergen similarly raised $95 million and Xoma $86 million. In secondary offerings, California Biotechnology, Cytogen, Enzon, Gensia, Immunogen, and Liposome all raised between $30 million and $40 million each, whereas T Cell Sciences and Calgene both raised about $20 million. Ecogen has a $13 million offering under way. Despite canceling a sale of its own stock, Genetics Institute raised about $43 million through an offering in a new research subsidiary, SciGenics.

Although revenue growth averaged more than 50% for the 34 companies surveyed by C&EN, only a handful have product sales or are profitable. Applied Bioscience, Biogen, Chiron, and Immucor continued to show a profit for the first half of 1991 as they did at the end of 1990. Amgen and Collagen dropped from the ranks of the profitable, but Genentech and Genzyme showed profits.

Two companies that recently turned the corner to profitability, Biogen and Chiron, continued along that route. Biogen had increased royalties from expanding sales of α-interferon as well as from its diagnostics licensees. The strong performance of Chiron's diagnostics joint venture with Ortho Diagnostics contributed to

Biotechnology stocks rising faster than overall market



a Reindexed to show relative change. Prices as of Friday's close each week. **b** Based on stock prices for Amgen, Applied Bioscience, Biogen, Centocor, Cetus, Chiron, Cytogen, Genentech, Genetics Institute, Immunex, Repligen, and Xoma. **c** Based on stock prices for Calgene, Crop Genetics, DNA Plant Technology, Ecogen, and Mycogen.

Only six biotech firms showed a profit in first-half 1991

	FIRST-HALF 1991					
	Revenues[a]	Earnings	Change from 1990		Profit margin[b]	
	($ thousands)		Revenues	Earnings	1991	1990
BIOPHARMACEUTICAL						
Amgen	$293,391	$ −11,508	128%	def	def	14%
Biogen	35,331	5,151	24	54%	15%	12
BioTechnology General	2,172	−3,752	24	def	def	def
California Biotech	4,539	−3,895	−21	def	def	def
Cambridge Biotech	13,164	−1,324	28	def	def	def
Centocor	24,510	−116,504	−17	def	def	0
Cetus	27,336	−35,804	21	def	def	def
Chiron	52,328	9,555	64	def	18	def
Cytogen	2,235	−9,523	−12	def	def	def
Genentech	261.407	30.724	12	65	12	8
Genetics Institute	26,277	−21,177	48	def	def	def
Genex	969	−1,799	−59	def	def	def
Gensia Pharmaceuticals	1,329	−14,311	nm	def	def	def
Genzyme	48,103	6,944	115	def	14	def
Immunex	24,565	−3,683	11	def	def	8
Immunogen	839	−5,800	40	def	def	def
Isis Pharmaceuticals	3,495	−3,116	5361	def	def	def
Liposome	3,707	−2,293	83	def	def	def
MGI Pharma	3,858	−4,859	36	def	def	def
Nova Pharmaceuticals	25.020	−7.526	169	def	def	def
Oncogene Science	3,968	−631	45	def	def	def
Regeneron	5,300	−1,474	488	def	def	def
Repligen	5,302	−2,872	−7	def	def	def
Ribi ImmunoChem	626	−1,581	−12	def	def	def
Synergen	8,335	−3,642	43	def	def	def
Xoma	10,053	−14,717	−14	def	def	def
AGRICULTURAL						
Crop Genetics	1,028	−2,878	282	def	def	def
DNA Plant Technology	5,214	−6,613	−26	def	def	def
Ecogen	3,467	−2,850	228	def	def	def
Mycogen	7,179	−1,804	−3	def	def	def
OTHERS						
Applied Bioscience	53,378	5,778	15	−6	11	13
Celgene	916	−3,204	37	def	def	def
Collagen	31,710	−5,448	23	def	def	8
Immucor	12,200	1,724	87	52	14	17

[a] Includes product sales, contract research, royalty, and interest revenues for first half of calendar year. [b] After-tax income as percentage of sales. **def** = deficit. **nm** = not meaningful.

its 18% profit margin, the highest of any company in the first half of the year.

Genentech's earnings reached $31 million on revenues of $261 million. Product sales for tissue plasminogen activator (TPA) and human growth hormone (HGH), and the recently approved γ-interferon, totaled $197 million. Revenue growth of 12% was due primarily to HGH sales. TPA sales dropped because of the release in March of the results of a major European study of competing blood clot dissolving agents. TPA's market share dropped in the second quarter from 60% to 53% and is expected to remain at about 50%. Sales are estimated at $180 million for 1991 as compared with more than $200 million in 1990.

The early April 1991 approval of Genzyme's Ceredase, although not currently produced by recombinant means, increased product sales 87% in the first half and the company reported a profit. With revenues up 115% to $48 million, Genzyme is confident of reaching its goal of $100 million in revenues for 1991.

Despite leading the industry with revenues of $293 million for the first half, a $129 million charge against earnings caused Amgen to report a deficit. The charge is part of a $164 million settlement with marketing licensee Ortho Biotech related to sales of erythropoietin. Without the charge, profits for the first half would have been $77 million. The company's second product, a granulocyte colony-stimulating factor (G-CSF), launched in early 1991, contributed about 25% to product sales.

Immunex's granulocyte macrophage CSF was approved in March and contributed to growth in product sales. However, for the half year, the company reported a loss because of increased expenses in expanding its sales, marketing, clinical, and scientific staff. Similarly, Centocor's loss of about $117 million resulted in part from investment in sales and marketing in the U.S. and Europe and a $70 million charge for acquired R&D. In the first quarter, the company's monoclonal antibody product for treating sepsis received a recommendation for approval in Europe.

Other big losses were reported by Genetics Institute and Cetus. Genetics Institute's resulted partly from an $11 million charge against earnings related to a patent suit against Amgen. Genetics Institute expects to be profitable in the second half of 1991. Cetus had increased revenues because of interleukin-2 sales in Europe and from its polymerase chain reaction technology, but reported a loss of $36 million for the first half. In July, Cetus and Chiron agreed to merge. Another older biotechnology firm to be acquired was Genex, purchased by Enzon in June.

On the agricultural side, biotechnology firms in general reported limited revenues and losses in the first half. The biggest turnaround was for Ecogen, although not yet profitable, with revenues tripling and product sales doubling over the same time last year. Yet the biggest event for this part of the industry was Mycogen's receiving Environmental Protection Agency approval of the first two genetically engineered microbial pesticides in early July. □

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European Community

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well prepared for 1992
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Volume 69, Number 37
CENEAR 69 (37) 1–48
ISSN 0009-2347

CHEMICAL & ENGINEERING
NEWS
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News of the Week

- **Panel urges drastic changes in U.S. technology policy, while White House stalls formation of institute to promote critical technologies.** Page 4
- **California chemists determine C_{76} fullerene to be an asymmetric molecule with a corkscrewlike twist to it.** Page 5
- **European Community to consider tax on carbon-dioxide-generating fuels, a plan that would hit the chemical industry hard.** Page 5
- **Edwin M. McMillan, Berkeley chemist who shared the 1951 Nobel Prize in chemistry, dies at age 84.** Page 6
- **EPA issues the first federal standards for municipal solid-waste landfills, governing everything from design to cleanup.** Page 6

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Business

In spite of falling price margins, ethylene production is up and headed for another record year, fueled by increasing exports and a building up of larger inventories. **Page 15**

Government

The chemist's role as expert witness in both civil and criminal cases, especially disputes over patents and those involving hazardous materials, is examined in chemical congress symposium; major reductions in nuclear weapons by the U.S. and the Soviet Union are urged in a recently released NAS report; EPA's new hazard ranking system is said to make it easier to get an accurate assessment at waste sites. **Page 19**

Science/Technology

More from the New York chemical congress: Enantiomeric intermediates for biologically, pharmacologically active products as well as enantiopure catalysts advance asymmetric synthesis; analytical chemistry reaps rewards of emerging spectroscopy; symposium underscores widespread concerns over future supply of chemists; phenols in fruits, vegetables, and green tea may reduce risk of cancer; new class of plant-derived proteins inhibits HIV in vitro; four Nobel Laureates share their thoughts on science and economics; and new fluorinating agents for enols developed. **Page 23**

Books

"Fusion: The Search for Endless Energy" by Robin Herman, takes on biases of its author, but is written in lively style. **Page 32**

News Focus

European chemical industry prepares for final push on remaining issues related to European Community's move to a single internal market in 1992—competition policy, energy, and the environment. **Page 7**

Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036
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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
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Subscription Rates 1991: Printed editions: nonmembers U.S. 1 yr. $95, 2 yr. $171; outside U.S. 1 yr. $131, 2 yr. $243. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $12. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management: CENTCOM LTD.
(For list of offices see page TK)
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LETTERS

CHEMICAL SAFETY

Explanation for CO absorbant solution explosion

The delayed explosion in a sealed bottle of undefined total volume initially containing 53 g of cupric chloride dihydrate ($CuCl_2 \cdot 2H_2O$) in 300 mL of concentrated hydrochloric acid and 75 g of copper turnings reported by Ihsan U. Shah (C&EN, July 29, page 4) is most likely due to the evolution of hydrogen gas by the oxidation by protons of the excess copper metal (left after formation of CuCl). Using half-cell potentials available in James E. Huheey's "Inorganic Chemistry," 3rd Edition [Harper & Rowe, New York (1983)], one calculates the 25 °C equilibrium constant for the reaction $H^+_{(aq)} + Cl^-_{(aq)} + Cu_{(s)} \rightarrow CuCl_{(s)} + \frac{1}{2}H_{2(g)}$ to be 4.82×10^{-3}.

The large molality (16.0) of concentrated hydrochloric acid, and the large estimated mean ionic activity coefficient at that concentration, 42.4 ["International Critical Tables," Vol. VII, National Academy of Sciences (1962)] yields an estimated equilibrium partial pressure of hydrogen in this system of 2.22×10^3 atmospheres! This calculation assumes that ion pairing in the hydrochloric acid solution is negligible and that the ideal gas law applies—both dubious assumptions.

However, we believe that the calculated pressure, although probably considerably different from the true equilibrium pressure, does strongly suggest that an explosion would be the expected result, if a significant amount of copper metal is left to stand under a concentrated hydrochloric acid solution for a prolonged period of time in a sealed system of limited gas-phase volume. For Shah's application, the prudent way of proceeding would seem to be to avoid using excess copper metal in preparing the cuprous chloride solution.

Thomas G. Dunne
Reed College
Portland, Ore.

A personal tribute

I've started to write this letter many times, but have not, to now, been able to marshal my thoughts. This letter is meant to be a personal tribute to Marjorie Gardner, who was a friend and mentor to me. [Gardner died April 19 (C&EN, June 3, page 35).] She personified personal courage, professional dedication, and almost single-minded devotion to the improvement of science education—in particular, chemical education.

My mind is filled with vignettes of Marge: standing to deliver her address upon the occasion of her selection to receive the Division of Chemical Education's foremost award for science education; a dynamo of activity as chairman of the first International Conference on Chemical Education held in the U.S. at the University of Maryland; a vigorous proponent for an international perspective in science education; the private meetings in her room, during ACS or National Science Teachers Association meetings, as we shared experiences; her leadership of "leader-teachers" at the Lawrence Hall of Science; our first face-to-face meeting at the University of Maryland, where I observed a writing session for the Interdisciplinary Approaches to Chemistry modules; her ever ready willingness to advise me; her personal and ongoing encouragement of me as I began to assess different roles for my future; presiding at the Division of ChemEd meetings, committee meetings—and on and on.

I am ever grateful to this woman and thankful that I had the time to thank her personally before the one insurmountable barrier overtook her. I'll miss her at meetings, I'll miss our phone calls, I'll miss her indomitable and indefatigable spirit.

Ethel L. Schultz
Section Head, Division of Teacher
Preparation & Enhancement
National Science Foundation
Washington, D.C.

Continued on page 47

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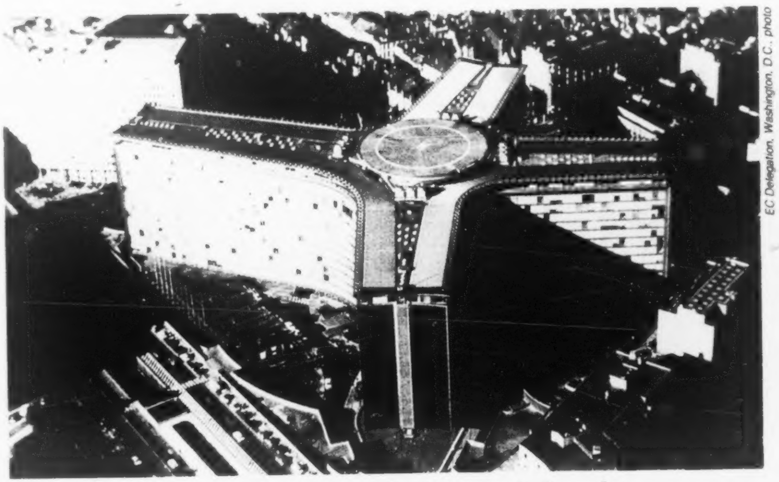
Chemical, Other Industries Ready For Push on Remaining EC-92 Issues

Most issues concerning Europe's pending single internal market have been dealt with, but the meaty topics of competition policy, energy, and the environment remain on chemical industry's plate

Patricia L. Layman, C&EN London



EC Delegation, Washington, D.C., photo

European Community's headquarters in Brussels

According to the sixth and most recent progress report on the European Community's move toward a single internal market, issued late in July by the EC Commission, of the 282 proposals gleaned from the original 301 in the 1985 White Paper on Completing the Internal Market, only 89 are left to be approved by the 12 member countries.

For the chemical industry though, much preliminary work has been accomplished. Most EC member nations have already adopted measures concerning customs formalities, technical harmonization and standards, pharmaceuticals and chemicals, commercial transport of goods, and intellectual property. But some sticky issues remain for the industry: competition policy, energy, and the environment.

Despite the large issues yet to be resolved, the member nations have waded through most of the white paper's proposals and, over all, seem to be weathering well the ups and downs implied by the proposed changes.

Six years can be a lifetime in politics. In fact, just three years ago, the topic at hand in the international political arena was "1992"—the year at the end of which the EC becomes a single, harmonized market. That was shortly after the EC passed the Single European Act, which would lead to the internal market.

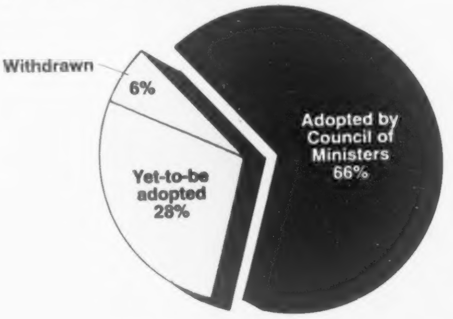
Companies, analysts, and consultants both inside and outside EC countries were caught up in a frenzy of activity, examining the opportunities and problems posed by a single community of 12 member countries, with a population of 320 million and a combined gross national product of $4.6 trillion.

Since then, however, attention has wandered. A brief but serious war in the Persian Gulf; the end of the Cold War, with one of its main protagonists in the process of disintegrating; and the shucking of communism and a turn to free market economies by Eastern Europe have all diverted attention from peaceful harmonization in Western Europe.

Nonetheless, the end of 1992, and the single European market, continues to approach relentlessly. The population is still there, larger by 20 million since eastern Germany has joined the former West Germany. The gross national product—excluding eastern Germany—was more than $6 trillion in 1990. And legislation designed to help bring about the single European market, continues to be passed.

Moreover, another nearly 500 additional laws have been proposed to enable the EC to bring to fruition its single, common market. Some of these laws extend the

EC's council has already adopted majority of "white paper" proposals



Total original proposals = 301

Source: European Community Committee of the American Chamber of Commerce in Belgium

reach of topics touched on by the original 282. Others add areas that were not mentioned by the 1985 white paper, including the crucial subjects of energy and the environment.

However, European management is no longer obsessed with the issue. For example, a survey by the Management Consultants Association in London in 1989 showed top executives in major European companies were highly concerned about 1992, second on a list only to "people availability." A similar survey early this year showed 1992 as a subject had slipped to seventh place. People availability, on the other hand, remained a pressing concern.

The difference, this time, is that companies and other organizations have had a chance to become accustomed to the idea of one single community of 12 countries. They have come to grips with potential problems, and have begun planning how to exploit opportunities. They also have become—just slightly—bored by the whole subject.

Few EC observers would go so far as one cynical British securities analyst who observes, "Nineteen ninety-two is last year's flavor of the month, and now everyone has forgotten it. If has receded to take its proper place in the scheme of human existence, namely zero."

Officials at the European Chemical Industry Council (CEFIC) in Brussels say bluntly about 1992 and the work toward a single European market, "It's a dead issue. The spirit and purpose of 1992 has been achieved, so we aren't concerned about it. We took the decision, we wouldn't make 1992 an industry.

"We are looking now at some of the unresolved issues—the political objectives, and so on. There are still some important things, such as the harmonization of standards, taxes, and excise duties; telecoms; transport. CEFIC has a continuing role, but we are addressing them as individual issues, not as a major 1992 effort."

Even in Washington, the Chemical Manufacturers Association says it has been sidetracked by other issues, such as the General Agreement on Tariffs & Trade and North American free trade issues.

"Analysis of how to work with EC-1992 issues is being done more by individual companies—the decisions will be up to them," says one official at CMA. "The broad interpretations our members needed have been taken care of. Now the companies are determining their own strategies."

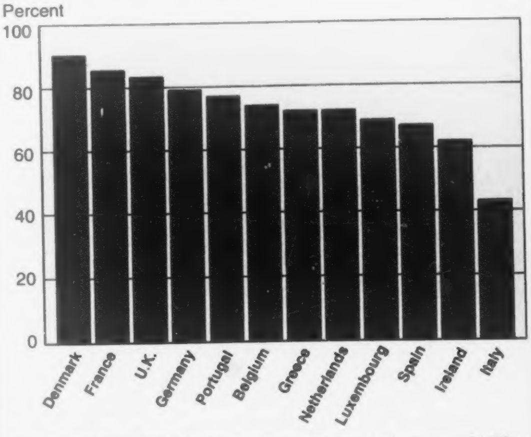
Many of that first batch of 282 proposals, which will have a particularly immediate impact on the chemical industry, have been implemented into national legislation by the member countries. The rate at which they and the second batch of proposals are being adopted, however, is rising.

According to the EC Commission's sixth report, the level of movement from community law into national law has risen from 69% in December 1990 to more than 73% in May 1991. In addition, the EC report says significant progress has been made in many areas. The more difficult problems lay in the general sphere. Actions taken in areas such as economics and finance, social laws, and mergers will have an impact upon all industries.

For example, the commission still has not received approval for a program to rationalize value-added, or sales, taxes. Value-added tax rates vary widely across the EC, with some countries having low rates for basic essentials and high rates for luxuries. At one point, Brussels hoped to set one rate throughout the 12 countries. However, the EC has decided that, just as different states in the U.S. can coexist economically as neighbors despite having different sales tax levels, so can EC countries have different value-added tax levels.

For U.S. companies, which early on worried that the subject of EC and 1992 was a smokescreen to conceal the rising barriers of "Fortress Europe," and that they would have no part of the lobbying and law-drafting

EC countries vary in percentage of "1992" measures enacted



Note: Percent reflects total of applicable measures the countries have reported to EC as adopted as of July 1991. **Source:** European Community

From concept to final vote, EC proposals move through intricate system

Spurred by a report in 1984 from the European Round Table (a Brussels-based group of European industrialists), Lord Cockfield, a British appointee to the Commission of the European Community, drafted in 1985 what became known as the White Paper from the Commission to the European Council on Completing the Internal Market.

The European Round Table report, urging pan-European movement toward a united home market, had dwelled solely on fiscal issues such as customs and harmonization of value-added sales taxes. Cockfield, who from 1985 to 1989 was the commissioner responsible for the internal market, customs union, taxation, and financial institutions, broadened the scope in setting out what was needed.

He pulled together all the outstanding issues his office was dealing with—about 300 measures—and divided them into four broad categories. And he picked an arbitrary target date—the end of 1992—to galvanize action, knowing that if there were no deadline, things would be put off and never get done at all.

The four broad categories were the freedom of movement of goods, people, capital, and services. Subsequent action by the EC added energy, health and safety, regional policy, research and technology, and trade policy—none of which had been on Cockfield's desk when he wrote his report in 1985, and hence were not included in the original paper.

The report was accepted by the EC's Council of Ministers, and the community eventually adopted it and the Single European Act, which became effective in 1987. The act enabled many measures to be passed by majority vote, rather than the unanimous vote that had been required up to that time. There was a complicated system set up for determining majority, but nonetheless it was a significant step forward for a group that was growing to the current total of 12 members.

Most of the original 300 measures, and nearly 500 additional ones added since 1988, are directives; only a few are regulations. Regulations have general application, are addressed to the governments of the member countries, and are immediately binding. Directives, on the other hand, set out results to be achieved by a deadline, but leave the "how" to each country, which must implement some form of national legislation in line with the directive's goals.

Draft proposals for legislation are drawn up by any one of the 23 specialized directorates general in the commission—rather akin to cabinet offices in an individual nation's government. After review by the commissioners, drafts are adopted as formal proposals and then submitted to the Council of Ministers. The council then consults the EC's European Parliament and the Economic & Social Committee, a free-standing "supercommittee" made up of employer, union, and general-interest representatives.

After negotiations and amendments in committees of both the Council of Ministers and the Parliament, a final proposal is written by the commission and sent to the council for a final vote.

Depending on the urgency of the matter, the enthusiasm of supporters, or the difficulty of balancing all interests, legislation can go from initial commission adoption to Council of Ministers' acceptance in a year—or it can take decades.

process, the EC Committee of the American Chamber of Commerce in Belgium has taken up the standard.

It now functions in parallel with the American Chamber of Commerce in Belgium, with a clearly defined role to play: namely, to represent the interests of European companies of U.S. parentage before the EC's legislative and administrative bodies. Its job is not only to comment on, but also, when appropriate, to propose policy and legislative initiatives to the EC.

The actions that any of the lobbying bodies take can only help companies throughout Europe, and given the importance of the chemical industry to the EC's member countries, the chemical industry will be a major beneficiary.

As Ian Butcher, commercial director of the consulting firm Kline S.A., in Brussels, points out, the EC chemical industry employs 2.1 million people, accounting for approximately 30% of world chemical production and sales, and is made up of 9000 chemical companies. By comparison, EC figures show that in 1989, the U.S. accounted for 23% of world chemical sales, and Japan, 17%.

Considering cutting barriers and reducing bureaucracy is a goal in the move to gain a single EC market, what will this mean for chemical producers?

Early on, Dow Europe conducted a preliminary investigation of the most important issues. Its estimate of operational cost savings: 1992 measures would save Dow Europe more than $50 million per year.

What Dow said at the time still holds: Truly global companies like ICI, IBM, and Dow, which already manage their businesses in Europe as interdependent parts of a global business, stand to benefit or to suffer far less from the impact of the single internal market than small or medium-size companies.

That's a point that Peter Gorle, managing director of London-based consultants Metra Martech, would agree with. "Nineteen ninety-two is about being big internationally, not about being big nationally," he says. The largest companies are already there, and small companies can always get by by nimbly serving niche markets.

The glitches, he adds, will come with the medium-size companies, many of whom still are not prepared for competing on a Europe-wide basis. Moreover, that will be true for both European and non-European companies.

There is a wide variety of barriers that the Single European Act sets out to eliminate—among them, physical barriers such as customs controls and border formalities, technical ones such as differing standards and quality norms, and fiscal ones such as value-added taxes and customs duties.

According to the EC's sixth report, the most progress has been accomplished in the area of customs formalities. "Simplification of border controls and transportation are certainly important to the chemical industry, which is a major user—it may be the largest user—of cross-border road transport in Europe," says David Sears, manager of government relations in Europe for Exxon Chemical International in Brussels.

There may still be some problems, but there have been definite improvements. "The difference between what has been accomplished and the way it used to be is obvious when you get to the borders with Switzerland," adds his colleague Bruce Guy, logistics manager.

Well under way, too, is an overhaul of shipping regulations on international transport and "cabotage"—prohibiting a trucker from collecting a load to deliver on the return journey. Just as in the U.S. when interstate transportation was deregulated, return-trip loads promise substantial freight savings for shippers.

In the field of technical standards, the EC report says legislation for chemicals is in place. The commission is now focusing on ensuring that member countries properly apply the directives, and it is involved in updating legislation in line with safety and environmental concerns, the report notes. A major deadline involves putting into effect, through the member countries, the law on classification and labeling of dangerous preparations.

There are a variety of issues with this, notes Rachel Geatches, a specialist in the product and regulatory affairs group at the Chemical Industries Association in London. The EC's concerns run from directives on food additives, including colors and sweeteners, to compiling a priority list for dangerous substances, to hazard assessment. The latter would lead to a clean bill of health or enacting some degree of control, up to a ban.

Similarly, work is also going on to harmonize standards, such as for testing and packaging. With different national lobbying groups, the EC perhaps understandably leans toward international standards—those, for example, of the United Nations, or the International Standards Organization. More immediately, however, the EC has also decided that what is acceptable in one member country, must be acceptable in the others.

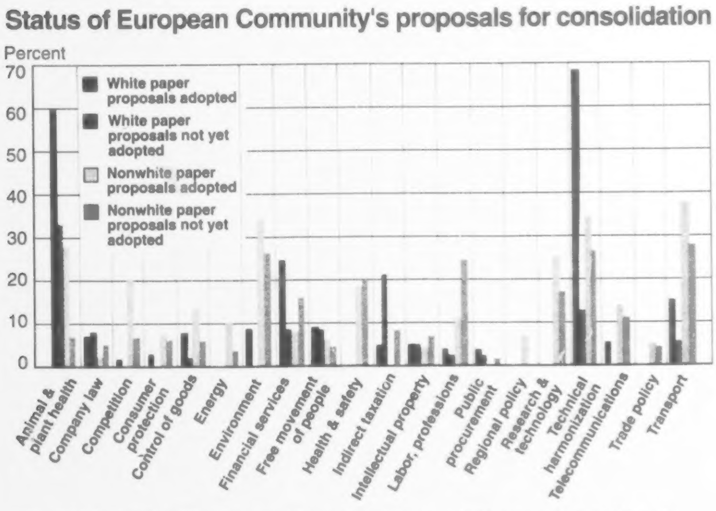
This has not always been an easy concept to sell across the EC, and has produced some singular challenges. For example, German brewers, proud of their centuries-old laws controlling beer content, fought hard—but unsuccessfully—to prevent beer being imported from other countries. Concern for purity? Protectionism? A bit of both? Whether consumer demand for the imports exists is beside the point; in this case, the EC has at least ensured consumer choice.

One marketing job for companies seeking to sell into the EC, then, is to judiciously select the first port of entry. Once accepted into that country, there will be acceptance throughout the European market. One international marketer, for example, contends that no importer with any sense at all would import goods into French ports—the French are simply too "notoriously prickly," even if that prickliness is skirting the line of permissibility under EC law. The solution? Import into Rotterdam or other more welcoming sites.

However, the most significant areas of legislative change for 1992 for the chemical industry—competition policy, energy, and the environment—are areas the latest EC report touches upon only briefly, if at all.

Competition policy, involving the thorny question of national aid to companies or industries, is particularly important in the chemical industry, which has a heavy representation of nationalized companies.

Notes Keith Wey, chief economist with the Chemical Industries Association, "Because of considerations given to regional problems and funding, some of the structural problems aren't being dealt with. For example, if a company is funded by the state, with terrific capital spending when by all commercial standards it should be shut down, that puts other companies at a disadvantage—or out of business."



Status of European Community's proposals for consolidation

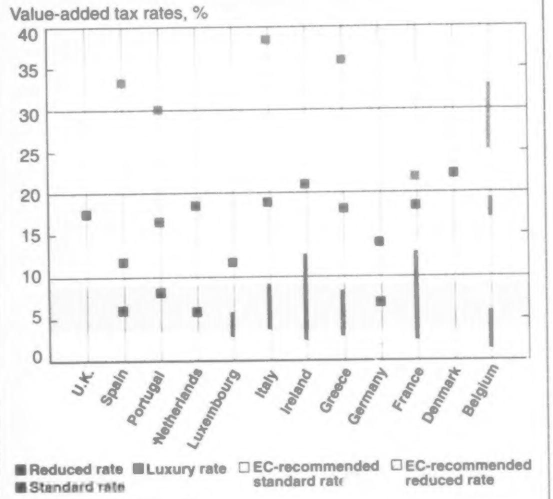
Note: Total "white paper" proposals = 282. Total "nonwhite paper" proposals = 490. **Source:** European Community Committee of the American Chamber of Commerce in Belgium

Environmental legislation wasn't part of the 1985 white paper, but its importance has become inarguable. And it is one area that will have an impact on the chemical industry—and one of the most troublesome impacts.

The topic of recycling, in particular, will trouble the chemical industry, predicts Metra Martech's Gorle. The EC's environmental activities for action, legislative input, and so on, cut across the board, through the activities of all the other groups within the commission.

However, there is a danger that unified, EC-wide environmental regulations are being preempted by national laws, a trend that alarms chemical companies. Not all the na-

Member nations mostly follow European Community's suggested tax rates



Source: European Community

tional efforts work. As Gorle notes, the Italian government planned a law banning nonrecyclable packaging, but such a law was not allowed by the EC.

On the other hand, the German government has taken a harder line, hard enough that the U.K. and French governments are complaining to the EC Commission. At least one chemical marketer, in fact, grumbles, "I'm not concerned about Fortress Europe—I am concerned about Fortress Germany."

The German initiative for recycling takes everything one step backward: If you sell or import a product, you have to take the packaging back, and—in order of preferability—reuse the packaging, recycle it, or dispose of it. It will be annoying enough for German companies or companies near their sales areas. But for companies hundreds or thousands of miles away, the prospect of dealing with unwanted packaging may prove an effective barrier to entry.

Among the benefits of EC-92, predicts Kline's Butcher, will be cheaper electrical energy prices, because of lowered costs from "common carrier" across-border sales.

However, the EC's other actions on energy threaten to override any benefits, believes Stephen Telegdy, Dow Europe's director of government affairs.

"The commission has correctly recognized that European energy markets need a closer look. For example, why should the natural gas price be coupled to the oil price? We support the EC initiative to liberalize the energy market," he says, but are unhappy with the slow progress being made.

One of the problems, as he sees it, is that member countries with a strong energy-supply industry, and a tradition of exempting government or private distributors from generally accepted rules of fair competition, strongly oppose the EC's efforts to liberalize European energy markets. And energy users, who might have protested the inaction, have traditionally been less well organized, and less vocal than energy lobbies.

That's a point that is not universally supported throughout the chemical industry. Chemical operations of oil companies, for example, would find it difficult to accept the same view. One marketer says, however, "We agree that there should be a thought-out policy. For example, electricity is the easiest to share, and it is not yet. The more you can share, the better."

European chemical producers firmly believe that—by and large—concerns about a Fortress Europe are groundless. That is not to say there won't be pressures. As another marketer notes, "Europe is full of companies that are protectionist." Pork-barrel politics are just as important in Europe as they are in the U.S.

Nevertheless, protectionism is not being written into the single European market by design. In fact, "EC standards will help overcome the oddities of national requirements, to keep restrictive measures at bay," points out Exxon's Sears. In a sense this is a return to the philosophy of the EC when it was founded, for totally nonrestrictive measures that would benefit anyone established and operating in the community.

What such factors as pan-EC standards and acceptance will not mean, however, is that non-European marketers will have a red carpet rolled out for them. Just as a U.S. East Coast producer would have to conduct market research in other areas of the U.S. before rolling out a product launch, so market research will become increasingly important for success in the EC.

A producer will have to become aware of packaging and product standards; of local or regional customer demands; of the relative advantages or disadvantages between building a grass-roots plant, or setting up a joint venture. But that kind of basic, slogging market research will be essential for any new marketer, even a European one.

Ultimately, the most serious pressures on EC will come on its own structure, as the number of member countries expands. The requirement for unanimity in voting by the Council of Ministers, one from each country, for example, for legislation on social and fiscal matters, will become more and more difficult as the community expands from its present 12 to as many as 24.

And expansion is coming, no question. The EC is currently processing applications for membership from Austria, Sweden, Cyprus, Malta, and Turkey. Finland and Norway are expected to apply next year. The commission is working on proposals that will put Hungary, Poland, and Czechoslovakia on the road to eventual membership. And many political analysts say those proposals will eventually extend to Romania, Bulgaria, and even Albania. The three Baltic states, now independent, likely will be part of the process as well.

No matter how many countries there are, however, Kline's Butcher says, "The EC really does want to open the market up—that is an official supranational position."

And, says the EC itself in its recent progress report, "Completion of the internal market for 1993 is an irreversible process, now entering the final straight." ☐

Ethylene Producers' Margins Drift Down As Output Climbs

Strong production growth for ethylene in first half spurred by rising exports and inventory building fails to boost profits as price cutting continues

Bruce F. Greek, C&EN Houston

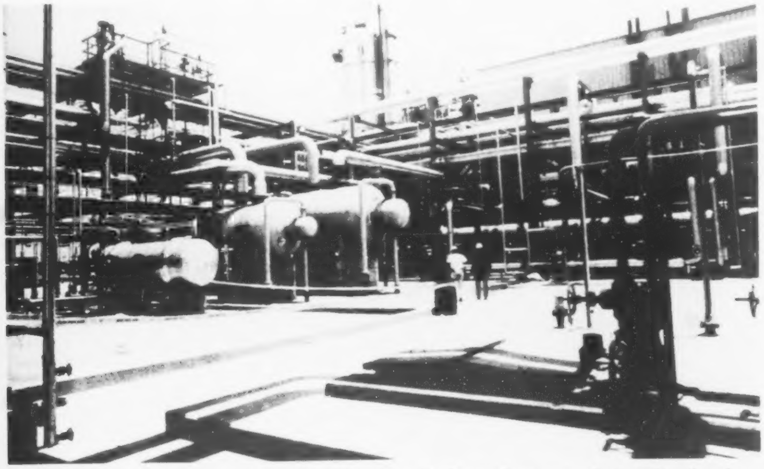
Despite shrinking price margins, ethylene producers expect another record volume year in 1991. Unusually strong exports of ethylene derivatives—especially polymers and polymer intermediates—and the building of larger inventories likely will boost this year's output to close to 40 billion lb.

However, domestic consumption of ethylene derivatives is declining, mostly because of the recession. Prices for ethylene and its derivatives plunged in the first half of the year, drastically cutting returns on the huge investment in plants.

The rise in output and sales could bring the value of ethylene produced in the U.S. this year to more than $7.5 billion. That production value would not set a record, however, because last year's average selling price was about one third more than the projected selling price for 1991. In addition, annual output will increase much less than a third.

Price margins are expected to continue to fall for the remainder of 1991, but not at the rate seen earlier in the year, says Hugh S. Pylant, a senior consultant at Houston-based Pace Consultants. Production of ethylene also may drop later this year from levels of the first half of 1991. Forecasts of sizable declines in output over the past few months, however, have proved to be wrong.

Unexpected events have complicated the forecasting for ethylene in 1991. Sizable capacity expansions are coming on stream later than scheduled. Export demand for ethylene polymers and other derivatives has grown more than forecast, and demand has remained high longer than was expected earlier this year, says John S. Doerr, who heads International PC, a Houston-based consulting firm specializing in ethylene markets.



Westlake recently started up 1 billion lb ethylene plant near Lake Charles, La.

Rising inventories of ethylene indicate that supply continues to be more than adequate. Problems at steam crackers have been numerous, but not serious enough to cause long outages.

Because of feedstock price variations, frequent changes of feedstocks are made in steam crackers that produce ethylene. Costs, therefore, have been volatile because crude oil prices are settling out higher than was anticipated at the end of the Persian Gulf War. Prices of light hydrocarbons—ethane and propane (widely used in steam crackers to make ethylene)—have fluctuated, influenced by small changes in inventories during the spring and summer, says Pylant.

Ethylene output in the first half of 1991 was about 19.6 billion lb, according to a survey of petrochemical production conducted by Ernst & Young for the National Petroleum Refiners Association (NPRA). The preliminary report on production of synthetic organic chemicals from the U.S. International Trade Commission estimates ethylene production was 19.5 billion lb in the first half of the year. Industry sources call this an unusually close agreement. This first-half output is up more than 10% over first-half 1990.

In the second quarter of 1991, production of ethylene declined slightly—about 3%—from production during the same quarter of 1990, according to the NPRA survey. The third-quarter production will be very close to the second quarter, according to some industry sources along the Gulf Coast. During July and August, plant problems caused minor losses in production. Planned shutdowns for maintenance work this month will largely be offset by

Ethylene use in exported polymers up 64% in first-half 1991

Millions of lb	First-half exports 1991	First-half exports 1990	First-half exports % change	Ethylene consumed in product exported in first half 1991	Ethylene consumed in product exported in first half 1990	Ethylene consumed in product exported in first half Change
Low-density polyethylene	678	399	70%	692	407	285
Linear low-density polyethylene	248	109	127	231	101	130
High-density polyethylene	461	330	40	470	337	133
Polystyrene	118	82	44	35	25	10
Polyvinyl chloride	774	469	65	372	225	147
TOTAL				**1800**	**1095**	**705**

Sources: Committee on Resin Statistics of the Society of the Plastics Industry, C&EN estimates

startup of new capacity or by startup of older capacity that has been idle for a few months.

Earlier in this quarter Westlake Petrochemical dedicated a 1 billion lb-per-year plant near Lake Charles, La., raising operable nameplate annual capacity for ethylene to about 44 billion lb at the end of the third quarter. For all of 1991, the average nameplate capacity is expected to total from about 1 billion to 2 billion lb less, owing to partial operation of Westlake's and Quantum Chemical's new plants. The Quantum plant began operation during the first quarter of the year.

Because of its startup during the middle of the first quarter of 1991, Quantum's plant, at Deer Park, Tex., likely will produce a maximum of 1 billion lb of ethylene this year. Westlake, with a mid-third-quarter startup, could put out as much as 400 million lb of ethylene this year, according to Michael Horvath Jr., a principal in Petrocon Associates, a consulting firm in Houston.

The only other large-capacity expansion for ethylene expected this year is Phillips 66's 1.5 billion lb capacity unit nearing completion at Sweeny, Tex. Although mechanical work is almost finished, the company says commercial operation will not begin until the fourth quarter. Because glitches often develop during startup of olefins plants, no significant ethylene output is expected from the Phillips expansion in 1991.

Various process improvements at other steam crackers will add to capacity, but in an unknown quantity. Because prices are declining and surplus capacity remains, there is little incentive for making improvements except during maintenance shutdowns. Consequently, the incremental capacity creep from process improvements during 1991 likely will be small, possibly about 500 million lb.

A huge part of the 1991 capacity expansions for ethylene will be used captively. For example, James Chao, president of Westlake, pointed out at his ethylene plant dedication that Westlake Polymers, another part of the Westlake Group, operates a 720 million lb-per-year polyethylene plant less than two miles away from the ethylene plant. The company has a 1 billion lb vinyl chloride plant at Calvert City, Ky., and also is building a styrene plant near the ethylene plant.

Quantum has plants that make all three types of polyethylene at several U.S. locations. The company also has other ethylene units. Despite the addition of 1.5 billion lb of ethylene capacity, Quantum will be able to make only 75% of its ethylene requirements, according to a spokesman.

Phillips also has large captive requirements for ethylene but they are not equal to its potential capacity. When the new unit at Sweeny comes on stream, Phillips will have about 4 billion lb of capacity at that location. After it rebuilds the polyethylene capacity destroyed in an explosion and fire almost two years ago, Phillips will still have captive use that is well below its capacity and will remain a major seller of ethylene.

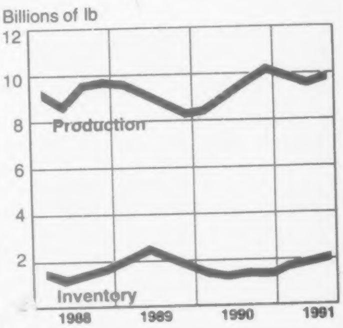
According to Gulf Coast sources, it is uncertain whether Phillips' new capacity and additional expansions in 1992 will be as fully utilized as its current operating capacity. Most of the increased output in 1991 has gone to exports or to inventory, points out John R. Hodson of Hodson & Associates in Houston. For most big-volume uses such as polymers, U.S. ethylene derivative consumption has slipped.

Exports of ethylene polymer derivatives are up more than 100% in a few instances, according to data compiled by the Committee on Resin Statistics of the Society of the Plastics Industry. For example, exports of linear low-density polyethylene were 248 million lb in the first six months of 1991, up 127% from first-half 1990. Exports of conventional low-density polyethylene increased 70% in the first half from a year earlier to 678 million lb.

Ethylene use also is increasing because imports of polymers have fallen. Imports of polyethylenes have dropped by sizable percentages in the first half of 1991, according to the SPI data. The imports, largely from Canada, offset U.S. production and use of ethylene. Imports of linear low-density polyethylene, largest in volume of the polyethylenes, fell to 316 million lb in the first half, down nearly 26% from the first half of 1990.

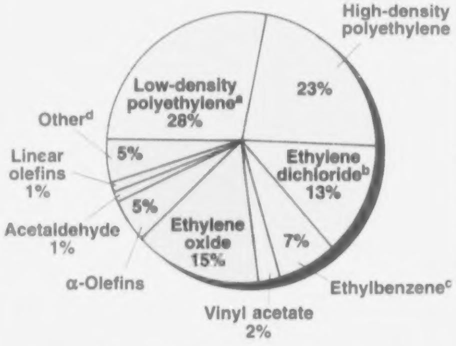
Other ethylene derivatives also have had large increases in export demand. For example, in the first six months of this year, exports of ethylene glycol increased 44% from the comparable 1990 period to 531 million lb, resulting in increased exports

Ethylene output, inventory follow similar pattern



Note: Production in fourth-quarter 1989 and first-quarter 1990 limited by freeze damage to plants, not demand reduction. Third-quarter 1991 is C&EN estimate. **Source:** National Petroleum Refiners Association of the equivalent of 101 million lb of ethylene. Vinyl chloride exports more than doubled, to 1.02 billion lb. Increased vinyl chloride exports accounted for the equivalent of an additional 278 million lb of exported ethylene in the year's first six months.

Polymers, polymer intermediates dominate ethylene uses



Estimated 1991 consumption[e] = 37.8 billion lb

a Includes linear low-density forms. b Mostly for vinyl chloride. c Mostly for styrene. d Includes ethanol, ethylene-propylene rubber, ethyl chloride, aluminum alkyls, other intermediates, and miscellaneous uses. e Does not include inventory changes. **Source:** Pace Consultants

Exports of ethylene derivatives in the first half took more than 1.2 billion lb of ethylene. This estimate includes ethylene used in polymers, ethylene glycol, vinyl chloride, and ethylene dichloride (the precursor of vinyl chloride). Additional small increases in ethylene exports could have come from other derivatives.

These increased exports of ethylene as derivatives easily account for much of the increase in ethylene production during the first half, points out Doerr. The remainder can be accounted for by lower imports of polyethylenes and by the additions to inventories.

NPRA data on inventories of ethylene show an increase of 195 million lb in the first quarter of 1991 and 109 million lb in the second quarter. At the end of second-quarter 1991, inventories were more than 1.8 billion lb, up 31% over those at the end of the second quarter of 1990.

How long the boom in exports of ethylene derivatives will continue could be a key factor in slowing down the decline in margins and holding up operating rates. The potential impact on U.S. exports by the recent startups of various ethylene and derivative plants in South Korea and other countries of the Far East is unclear, as is the future impact of similar plants now under construction.

Some sources suggest that demand growth for plastics and fibers based on ethylene in the Far East will require all of the output from the new and future plants in the region, as well as imports from the U.S. Others believe that derivative exports will hold up only as long as large quantities of consumer products containing ethylene derivatives are exported to the U.S. from the Far East. As the U.S. continues its slow recovery from the recession, demand for such imported goods can be expected to increase, and that could keep exports of ethylene derivatives strong.

Perceived overcapacity ahead for ethylene, coupled with high output, will keep pressure on selling prices, sources say. Most contract ethylene prices—which less than a year ago were more than 30 cents per lb for a short time—settled at 19 cents per lb for July, off a cent from June. In July 1990, contract prices settled at 23 cents per lb.

Future prices are expected to decline because important segments of the merchant market are being turned into captive markets. However, the decline will have to slow should producers' costs exceed income. In July, total production costs—those for feedstocks, plant operation, depreciation, and overhead—reduced margins to the range of 3 to 8 cents per lb, depending on feedstock, says Pylant. If corporate overhead, feedstock delivery charges, and ethylene and coproduct delivery costs are included, some producers may have little net profit.

To take advantage of varying feedstock prices, many of the older steam crackers have been modified so that they can handle nearly all kinds of feedstocks, ranging from ethane to gas oils of different boiling ranges. Large quantities of coproducts—propylene, butadiene, and a pyrolysis gasoline stream containing various aromatics—are made if heavier hydrocarbons are used. The newer plants of Quantum and Westlake are designed to crack only the light hydrocarbons, because the owners have little or no use for such coproducts.

Selling prices of many of the coproducts have declined as much as or more than ethylene. The credits given to the cost of production of ethylene from the coproducts, therefore, do little to lower the cost. Costs of purifying and handling the coproducts reduce those credits even further. Consequently, the heavier hydrocarbon streams, such as gas oil, are now less economical for use in making ethylene.

Gas oils and similar streams continue to be used in steam crackers because they no longer have as much value in making gasoline components as they once did. A steam cracker will upgrade these hydrocarbons to more valuable products, but the profitability will be lower than if ethane were used under current economic conditions. If the total economics of making fuels and chemicals are integrated, for some companies operating steam crackers on feedstocks made up of high fractions of gas oils can be best.

These older steam crackers using heavy feedstocks in the current economic situation have significantly lower margins from making ethylene, sources say. Depreciation charges are lower because of the age of the equipment, but other costs are higher, including energy requirements due to lower efficiencies of old equipment. These units could be headed for the scrap pile.

If exports of ethylene derivatives fall and U.S. consumption doesn't rise enough to offset the export decline, then the additional pressure on prices for any length of time could cause some capacity shutdowns and some deferral of plans to expand capacity. This situation, reminiscent of the mid-1980s, would set the stage for another tight supply by the mid-1990s. □

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NEWS

Drugs for Diabetes

New types of treatment
in clinical trials
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CHEMICAL & ENGINEERING
NEWS
SEPTEMBER 30, 1991

Volume 69, Number 39
CENEAR 69 (39) 1-84
ISSN 0009-2347

News of the Week

- **American Home Products plans to acquire biopharmaceuticals maker Genetics Institute in a deal valued at $666 million.** Page 6
- **Germany's Bayer will reorganize its U.S. holding company, Bayer USA, as an operating firm, which will be called Miles Inc.** Page 7
- **St. Louis mother convicted of murdering her baby by ethylene glycol poisoning has been cleared following evidence of lab errors and that cause of death was a rare genetic disease.** Page 7
- **Soviet Academy of Sciences may break up as a result of the growing autonomy of the Soviet Union's republics, says White House science adviser D. Allan Bromley.** Page 8
- **New electronic medical journal, described as the first peer-reviewed science journal to be distributed on-line, will be launched by AAAS and Online Computer Library Center Inc.** Page 8

Cover: Hexamer of insulin. Slide produced by R. E. Hubbard and M. J. Hartshorn of the University of York, England, using the Quanta program from x-ray crystallographic data determined by G. G. Dodson and colleagues at York. Photo courtesy of Polygen Corp./Molecular Simulations

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Business

Air Products' chief Dexter Baker, 1991 SCI medalist, points to need for opening markets worldwide, improving public's image of industry, attracting more students to careers in chemistry. **Page 13**

Government

White House Office of Science & Technology Policy faces a hard look in hearings slated for next month as pressure builds on science adviser Bromley to restructure office's technology policy. **Page 17**

NIH can significantly increase the number of grants it awards as the result of cost controls installed during the past year. **Page 19**

Science/Technology

Site-directed mutagenesis has handed chemists a powerful tool for probing protein reactions in biological systems at the molecular level. **Page 23**

Titanium silicate molecular sieves may find applications in fields of adsorption and catalysis. **Page 31**

Approaches to optimizing bioreactor production of antibodies may result from research at Rensselaer Polytechnic Institute. **Page 32**

ACS News

Materials Chemistry Secretariat was formed by 11 divisions at recent ACS national meeting in New York. **Page 61**

Product Report

Human insulin, insulinlike compounds, and other drugs aimed at treating diabetes and its complications are being developed by medicinal chemists and biotechnologists. **Page 35**

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Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210.

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LETTERS

Supporting the space station

It has come to my attention that there is considerable concern that the money allocated to space station *Freedom* is cutting into other programs. I am understandably concerned that chemistry and chemical engineering programs may be adversely affected.

However, I feel that we should not be stampeded into undermining the space station. It will pioneer many new technologies that will benefit chemistry and many other disciplines in the coming years. It will provide a springboard to the eventual exploitation of the resources of the Moon and beyond, as the shrinking resources of Earth are competed for by all nations. It will employ many fine professionals such as biochemist/astronaut Shannon W. Lucid (C&EN, Aug. 19, page 7). It will help inspire future chemical professionals, in part due to the broad interest enjoyed by the space programs. It should be supported in addition to seeking increased funding for chemistry programs.

Robbing Peter to pay Paul will not solve the budget crunch caused in large part by the $100 billion-plus savings and loan disaster—only shift the focus. Loss of these research monies in the long run will prove a greater disaster. Eating the seed guarantees a smaller crop. Those who follow us will not thank us any more than the shortsighted individuals to which the vacant steel mills and razed support industries stand as grim testament.

William M. Cress
Freedom, Pa.

Cold fusion

The suggestion by Albert H. Alberts (C&EN, Aug. 12, page 3) that an intrinsic artifact in the isoperibolic calorimetric method may have led many cold fusion research groups astray is simply not valid. The possible error sources reported by Frederick T. Wagner et al., [*J. Electroanal. Chem.*, **295,** 393 (1990)] involving the operation of a calibration heater in the cell and the decreasing electrolyte level during electrolysis are carefully considered by most research groups that use isoperibolic calorimetric methods. We did not use an in-cell calibration heater in our experiments; hence that error source can be quickly dismissed. We reported and corrected for the changing electrolyte level effect in a previous publication [*J. Fusion Energy*, **9,** 333 (1990)]. A modified design has minimized the effect of the electrolyte level in our present calorimetric cells [*J. Electroanal. Chem.*, **296,** 241 (1990)]. As pointed out by Wagner et al., isoperibolic calorimetric methods can give accurate results when these error sources are taken into account.

I hope other readers did not miss the major point of our preliminary note on excess heat and concurrent helium production in cold fusion experiments [*J. Electroanal. Chem.*, **304,** 271 (1991)]. To my knowledge, helium can be produced from electrochemical cells containing D_2O, LiOD, Pd, and Pt only by fusion processes or elemental transmutations. No calorimetric artifact can explain our helium finding. Regarding the apparent lack of refereeing, I have had previous publications on unrelated subjects accepted by action of the editor. Many scientists, such as Alberts, have now studied our preliminary note or have listened to various presentations regarding this work, yet no significant flaws have been uncovered.

The observation of cold fusion effects in electrochemical cells requires special attention to many details such as cell geometry, electrode arrangements, current density, and control of impurities as well as considerable patience. I am not surprised that many research groups were unsuccessful in their few weeks of frenetic cold fusion research. It took our group over five months of investigating various parameters before any excess heat effects were observed. A new method reported by S. Szpak et al. [*J. Electroanal. Chem.*, **302,** 255 (1991)] involving the codeposition of palladium and deuterium from D_2O solutions gives a more reliable and rapid initiation of the Fleischmann-Pons effects. It should be possible for other groups to verify our excess heat

Correction

- Sept. 9, page 41: The product generated by the organolithium reagent should properly have been named 3-methylheptane, not 2-ethylhexane.

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Cost controls help NIH boost grants awarded

Cost controls put in place over the past year are allowing the National Institutes of Health, which funds about 30% of all academic chemistry research, to increase significantly the number of grants it awards. At the National Institute of General Medical Sciences (NIGMS), the source of most NIH chemistry funds, about one third of applicants for new or competing renewal grants were successful this year, compared with about one out of five in fiscal 1990.

That's good news for chemists worried and frustrated over the tight grant situation of the past few years. NIGMS estimates it will fund 860 new and competing renewal grants this fiscal year, as opposed to 623 last year. But while the number of new grants being awarded is increasing, NIH cost-management policies mean that those grants are for less money and for fewer years than most applicants hoped.

NIH's cost-management plan, put in place after much debate last winter, was developed in response to a request from Congress after it was deluged with complaints from researchers about a funding crisis. Congress wanted to know why the healthy increases it had been approving in the NIH budget didn't seem to be enough to go around. It asked NIH to develop a plan that would ensure better stability and cost-effectiveness. Among other things, it specifically instructed NIH to address the increasing average duration of grants and the rapidly escalating cost of the average grant.

In the mid-1980s, NIH decided to increase the length of many of its grant awards to five years. The scientific community had advised that longer term grants would mean the time-consuming chore of preparing grant applications would roll around less often.

An unintended, albeit foreseeable, consequence of the decision was to decrease the funds available for new grants. Whenever a grant is awarded, money must be set aside from future-year budgets to cover the grant's entire term. The longer the average grant, the less uncommitted money is

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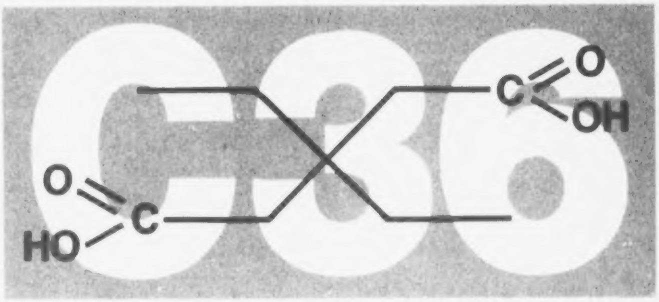

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NIGMS has held cost increases below inflation rate . . .

Average total cost	1991[a]	1990	% change
Total research project grants	**$183,856**	**$175,276**	**4.9%**
New research grant awards	154,355	152,355	1.3
Competing renewal awards	205,345	213,174	−3.7
Noncompeting continuation awards	185,636	172,706	7.5
Biomedical Research & Development Price Index			**6.0%**

. . . allowing steep rise in new and competing awards

Number of grants awarded	1991[a]	1990	% change
Total research project grants	**3227**	**3174**	**1.6%**
New grants and competing renewal awards	860	623	38.0

a Projected. **Source:** National Institute of General Medical Sciences

available for new proposals or renewals.

At Congress' instruction, NIH now is aiming for an average grant length of four years. According to W. Sue Shafer, NIGMS associate director for program activities, only 6% of the 700 or so regular grants—R01s, in NIH lingo—NIGMS had awarded by early September were for five years. About two thirds were for four years and the remainder for three. That meant 437 applications for five years of support were funded for only four.

Congress also told NIH to keep the increase in the cost of the average grant to within the Biomedical Research & Development Price Index (BRDPI). That index is calculated to include special expenses that push inflation for R&D higher than the general inflation rate. The BRDPI for 1991 is 5.99%.

NIGMS is projecting a 4.9% increase in the average cost of its total grant portfolio, which it estimates will number 3227 by the end of fiscal 1991. But that increase is not distributed evenly over the different classes of grants.

For example, the average cost of the noncompeting continuation awards that make up the bulk of the portfolio will rise 7.5% to about $185,000. A significant portion of that increase, according to Shafer, stems from the replacement of cheaper, older grants that have expired with more expensive ones made last year.

To balance the increase in continuation awards, which is well above the BRDPI, NIGMS held down the costs of new grants and grants being renewed. The average size of new grants in fiscal 1991 increased only 1.3% to about $154,000 over 1990. And competing renewal awards actually decreased 3.7% in average cost to about $205,000.

New NIGMS grants awarded in 1991 were funded at about 83% of the full amount recommended by the National Advisory General Medical Sciences Council, the policy-setting group that makes the final decisions on awards after the applications have been peer reviewed. Such cuts have been a common practice throughout NIH for years.

However, again on Congressional orders, NIH is giving up the unpopular practice of "downward negotiations." That is, although the grant budget is trimmed initially, it won't be cut any further in subsequent years of the grant.

According to NIGMS's analysis, without the combined effects of the cost-management strategies, NIGMS would have been able to fund only 400 competing awards in fiscal 1991, about one out of six applications. And the total portfolio would have numbered only about 2767, the lowest total since 1983.

Pamela Zurer

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CHEMICAL & ENGINEERING NEWS

Learning and Memory

Chemistry joins other sciences to unravel molecular bases of these processes

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CENEAR 69 (40) 1-72
ISSN 0009-2347

CHEMICAL & ENGINEERING NEWS

OCTOBER 7, 1991

News of the Week

- **Indian Supreme Court hands down decision on Bhopal disaster that upholds 1989 $470 million settlement, but opens Union Carbide to criminal charges.** **Page 4**
- **Government Accounting Office report says federal agencies are not adequately regulating environmental chemicals that cause harmful reproductive effects.** **Page 5**
- **Science and math achievement among U.S. elementary and secondary students increased slightly in 1980s but not enough, in some cases, to match early 1970s' scores.** **Page 5**
- **EPA announces measures to cut costs and expedite Superfund cleanups.** **Page 6**
- **Atmospheric scientists launch six-month mission to study ozone depletion in Arctic regions.** **Page 6**

Cover: Positron emission tomography scan of human brain. Photo courtesy of E. S. Garnett et al., Chedoke-McMaster Hospitals, Hamilton, Ontario, Canada

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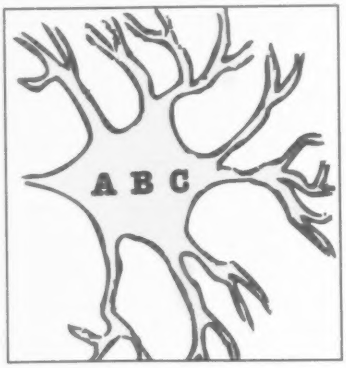

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
John Kistler Crum, Executive Director
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Subscription Rates 1991: Printed editions: nonmembers U.S. 1 yr. $95, 2 yr. $171; outside U.S. 1 yr. $131, 2 yr. $243. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $12. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

CHEMICAL SAFETY

Reactivity of perfluorocarbons

In a letter on chemical safety (C&EN, June 10, page 2), a group of Dow chemists alerted readers to the reactivity of perfluorocarbons toward oxidizers. In response to this letter, the vice president of Halocarbon Products countered (C&EN, Aug. 5, page 2) that saturated perfluorocarbons and chloroperfluorocarbons do not ignite in the presence of 2000 psig of oxygen gas even at 400 °C. He, therefore, concluded that before any recommendations in the safety letter on perfluorinated organic compounds are implemented, more information is needed.

In view of these conflicting letters I would like to call attention to two pertinent unpublished studies from our laboratories. In the first study, laboratory tests were carried out to duplicate the failure of an oxygen tank containing Teflon components during the *Apollo 13* mission in 1970. The conclusions reached at that time were:

- The combustion of Teflon in oxygen to give carbonyl fluoride is highly exothermic; for example, 148 kcal per mole. However, a powerful ignition source is required owing to the high activation energy of the reaction. The minimum ignition temperature is 465 °C, even under 7500 psi of oxygen gas.
- The ignition of Teflon tubing at −61 °C in supercritical oxygen at 900 psi O_2 pressure required a hot nickel-chromium wire as an initiator. The main combustion products were CO_2, CF_4, and COF_2.

In the second study on solid propellant NF_3-F_2 gas generators, it was found that mixtures of Teflon powder and NF_4^+ salts burn smoothly when initiated by conventional solid propellant ignitors. As in the case of oxygen, strong fluorooxidizers can react with Teflon in highly exothermic reactions to yield CF_4.

In conclusion, both of the previous letters raise valid points; namely, that fluorocarbons or Teflon, $(CF_2)_n$, are only half oxidized and are capable of undergoing highly exothermic combustion reactions with either oxo- or fluorooxidizers, and that the activation energies for these reactions are so high that under normal operating conditions it is very difficult to initiate these combustion reactions.

Karl O. Christe
Rocketdyne Division
Rockwell International Corp.
Canoga Park, Calif.

Licensing of chemists

The letter to the editor, "A real profession" (C&EN, Aug. 19, page 5), suggests that misuse of technology was responsible for the incidents at Bhopal and Chernobyl, the Ford Pinto fires, and the *Challenger* explosion, and proposes licensing of chemists as a means of enforcing their competence and ethics.

During many years of association with working chemists, both in academia and industry, [I have found that] they have been almost universally both capable in their areas of activity and of the highest ethics. The fact that recently reported incidents of unethical behavior are newsworthy suggests its rarity. Less glowing statements can be made about those who manage the activities of chemists. The pressures imposed upon chemists by the institutions they work for to publish more extensively, cut costs more deeply, and get to the marketplace more quickly are enormous. Ultimately, chemists are compelled to cut corners, and tragedy may result.

Corrections

- Sept. 16, page 2: In the letter on chemical safety, the estimated equilibrium partial pressure of hydrogen should be 5.0×10^6 atm, not 2.22×10^3.
- Sept. 23, page 3: In the letter on unnecessary journals, the impact of ever-more journals and ever-increasing subscription prices has been profound and disruptive for university libraries, not industry libraries.

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Biotechnology industry posts record revenues

Industry balance sheet shows growth

	Public companies			Industry total		
	1990-91	1989-90	% change	1990-91	1989-90	% change
Product sales ($ billions)	$ 2.86	$ 2.26	26%	$ 4.0	$ 2.9	38%
Revenues ($ billions)	$ 3.78	$ 3.08	23	$ 5.8	$ 4.7	23
Net loss ($ billions)	$ −0.81	$ −0.44	84	$ −2.9	$ −2.0	45
No. of companies	194	180	8	1,100	1,100	0
No. of employees	33,000	29,000	14	70,000	66,000	6

Note: Fiscal years ending in June. **Source:** Ernst & Young

Product sales for the biotechnology industry reached a record high of $4 billion for the fiscal year ending June 30. This 38% increase over the previous year was driven by Food & Drug Administration approval of 11 biopharmaceutical products, according to San Francisco-based professional services firm Ernst & Young's annual report on the biotechnology industry, "Biotech '92: Promise to Reality." Also, although the industry is dominated by health care companies, the first genetically engineered biopesticides, produced by Mycogen, received Environmental Protection Agency approval.

"The product trickle of previous years has turned into an outright flow," says Kenneth B. Lee, national director for life sciences industry services at Ernst & Young. "Almost as many products as were approved in total in years prior were approved this year."

The promise of the future was always exciting, explains G. Steven Burrill, Ernst & Young's national director of high-technology industry services, but biotechnology companies now are being evaluated by more traditional measures of success. Instead of hedging bets solely on promising R&D, intellectual property rights, and potential products, companies are being valued by benchmarks such as product sales, market size and penetration, stages of product development, and strategic alliances for commercialization. As a result, industry executives running established companies are changing their priorities and being "less entrepreneurial."

"It's an industry driven by very real products and very real companies," adds Burrill. "We are about to see Amgen as a leading company make its way into the Fortune 500—that would be [a] first for this industry." Amgen received FDA approval to market erythropoietin (EPO) in June 1989 and its second biopharmaceutical product, granulocyte colony-stimulating factor, this year. Sales of EPO by Amgen and its licensees could surpass $500 million in the near future. "There are only a handful of billion-dollar products in the pharmaceutical industry, so for any one of these [biotechnology firms] to have a billion-dollar product moves it into the big leagues instantly."

Other major biotechnology products include Genentech's tissue plasminogen activator, γ-interferon, and human growth hormone; along with human insulin, α-interferon, and granulocyte macrophage colony-stimulating factor developed by firms such as Biogen and Immunex. Another 17 products are awaiting FDA approval and more than 100 biopharmaceuticals are in various stages of clinical trials. Comments Lee, "There is still a tremendous amount of upside opportunity for biotechnology. The products usually come with substantial individual sales opportunity—$50 million to $100 million in annual sales."

However, most of the 1100 companies in the industry are small and need continued financing to fund R&D. "The uncertainty around the Persian Gulf War and economic news of the time tended to cause investment capital to move toward the health care industry," says Burrill. "And when the investors were looking for exciting stories, they looked much beyond the traditional drug companies and realized that [biotechnology] companies were bringing exciting new products to the market."

The success of companies such as Amgen, Genentech, Immunex, Biogen, Chiron, Genzyme, and Centocor attracted the attention of investors to the industry as a whole. Biotechnology has been in the midst of its biggest financing year ever, raising over $2 billion in the first six months of 1991. A record number of initial and secondary stock offerings among the 194 public companies has increased the overall industry market capitalization by 75%, to a record $35 billion.

"I think we can expect that as the sales flow continues to increase that the [stock] market will react favorably," Burrill adds. "But I think it is also fair to say that when one looks at the market, it will continue to be both volatile and event-driven." Patent issuances, court decisions regarding patent rights, regulatory issues such as product approvals or delays, and significant financings or strategic alliances are events that play a major role in the stock market valuation of individual companies and the industry as a whole.

In addition, as more companies move out of research into product development, explains Lee, the need for capital to build commercial infrastructure will increase substantially. A net loss of nearly $3 billion, 45% higher than the previous year, was reported for the industry. Strategic alliances with major companies, still numerous but down in number because of available capital from public markets, are expected to continue to be important.

Large, established biotechnology companies now have the ability to set up intra-industry alliances or make acquisitions. And, the number of startup companies has dropped with decreasing venture capital investment. With about 40 mergers and acquisitions in the past year, including those involving older, major companies such as Genentech, Cetus, Genex, and Genetics Institute, a net consolidation of the biotechnology industry may be on the horizon.

Ann Thayer

Henkel-Ecolab new force in cleaning market

In one sweep of the pen, the professional cleaning and hygiene business in Europe obtained a new market leader—a joint venture called Henkel-Ecolab, formed by Germany's Henkel and St. Paul, Minn.-based Ecolab Inc. Agreed to in July but officially launched late last month, the new company has projected annual sales of about $800 million this year, more than European sales of Anglo-Dutch producer Unilever, and of Diversey, owned by the Canadian brewing company Molson.

The Henkel-Ecolab venture was formed when Ecolab integrated its European business into the venture with Henkel, the largest shareholder in the Minnesota company, earlier this year. Henkel, in turn, split off its industrial and institutional operations from its larger businesses in detergents and chemicals to contribute to the venture. Ecolab continues to sell its products everywhere in the world except Europe. The resulting company, based in Düsseldorf, has some 3500 employees throughout Europe.

Not only is the new venture the European leader, but it also is in serious contention for market leadership worldwide, even though its sales are solely in Europe, says Ehrhart Schlüter, managing director of the new venture. Henkel-Ecolab's sales will be only slightly smaller than those of parent Ecolab, long the worldwide market leader, which now has about 8% of the market, and of Diversey, which through acquisitions this year has pulled up to that level, as well.

Those three companies, and Unilever, lead a worldwide industry mostly made up of hundreds of small- to medium-size local or regional companies. Worldwide sales of industrial and institutional cleaning and sanitation products are nearly $12 billion, of which Europe will account for $4.7 billion this year.

The long- to medium-term outlook is for growth of at least 10% per year, predicts Schlüter. Even the short-term outlook is good, at least for Henkel-Ecolab: Its sales in 1992 are expected to grow at least 10% over 1991, he adds.

Both Henkel and Ecolab are major companies in their respective markets. Ecolab, whose sales topped $1 billion in 1987, has long been the world's largest supplier of industrial cleaning and sanitation products. Henkel's sales in that area topped 1 billion deutsche marks in 1988—about $570 million—second only to Unilever in Western Europe.

The venture's research and development and service activities will be supported throughout Europe by Henkel's research center in Düsseldorf and by Ecolab's in St. Paul. The venture also will be able to tap into the laboratories of both parents for such specialist work as microbiological, ecological, and toxicological testing, and for packaging systems and process development.

More than 60% of the venture's production will come from its own plants, with additional output from Henkel's plants in Europe. The new company has set up three business units: GV, to focus on cleaning and sanitation for institutions, hospitals, and commercial laundries, among others; P3-F, to target the food and agricultural industries, and the pharmaceutical and cosmetics industries; and Ecolab, to provide cleaning products and dishwasher detergents for commercial kitchens such as at hotels and restaurants, caterers, and office cafeterias.

With the combination of Henkel's and Ecolab's plants and sales offices scattered across Europe, the joint venture will have a presence in some 17 countries, stretching from Turkey in the east to Norway in Scandinavia. Plants are in Ireland, the U.K., France, Belgium, the Netherlands, Germany, Switzerland, Italy, and Denmark. And the company already has established sales offices in Poland, Czechoslovakia, Hungary, and Yugoslavia.

The three Henkel-Ecolab units roughly cover the spread of the traditional industrial and institutional market. Suppliers to this market serve segments such as textiles cleaning for hospitals and commercial laundries; hard-surface cleaning in industrial and institutional plants, offices, and other locations; restaurants and hospital hygiene; and cleaners and disinfectants for the food and agricultural industries.

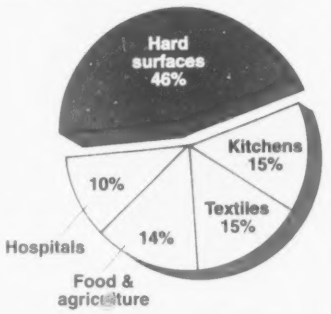
Suppliers have grown up in the general vicinity of where they are needed—supplying bottle-washing detergents for the local brewery, for example. More and more, however, the industry is taking on an international look. An international brewer, say, might wish to rely on transnational suppliers able to meet international safety, product, and environmental standards. Companies in the business also increasingly supply not just chemicals, but dispensing and control systems, as well as the appropriate training courses for customers' personnel.

All these developments are part of what Henkel-Ecolab sees as part of the industry's revised thinking on the relationship of what is offered and what is actually needed. Not only are internationally comparable products one of the major requirements, the company argues, but so also is the capability for international service and consultation.

Those requirements, in turn, are driving the need for size among suppliers. In response, there has been a consolidation of companies. The trend has been going on for a number of years but has accelerated recently. For example, earlier this year, Diversey—which formerly had about 5% of the worldwide market—took a major step forward with the acquisition of Chemed's DuBois Chemicals subsidiary, boosting its market share to about 8%.

Patricia Layman

Hard surfaces make up 46% of industrial cleaners market



Total estimated 1991 sales = $4.70 billion

Source: Henkel-Ecolab

Voluntary Retirements Obscure Employment Picture for Chemists

What is a termination? What about the case of a veteran employee who accepts "voluntary" early retirement, but does so because of fear that turning it down could soon be followed by involuntary dismissal on less favorable terms? What about early retirement or resignation that occurs because the only alternative is transfer to a less desirable job or location?

These are some of the questions that are of increasing concern to ACS's Committee on Professional Relations (CPR) as it strives to maintain the accuracy and fairness of its long-standing program of investigating and reporting on mass terminations of chemists.

The committee defines a mass termination as a situation in which the employment of three or more chemical professionals is terminated within a three-month period for reasons other than properly documented inadequate performance, completion of a contract, or cause. Implicit in this definition has always been the involuntary nature of the terminations.

In its latest termination report, the 32nd in a series dating back to 1974, CPR points to the increasing use of early retirement incentive programs. The committee predicts this trend likely will continue as the "baby boom" generation ages.

The report also points out that the committee's conservative stance of counting only terminations that are unambiguously involuntary could be causing it to understate weaknesses in the current employment situation for chemists—especially older ones.

Another concern of CPR is the relative dearth of information from terminees themselves. The committee bases its reports on data supplied by both terminees and employers. Employers usually respond when asked. But normally CPR will approach an employer only after it has received data on a termination from at least three individuals involved. This is not always easy to do. Hence, some mass terminations may not be fully investigated and not reported.

At one time, committee members thought terminees might be reluctant to provide data to ACS because of secrecy clauses in their termination agreements. However, returns of a modified questionnaire used by the committee for the first time last year indicate this likely is not the case.

CPR reported only three completed termination investigations in each of its two previous reports. These were the smallest reports ever. The average for all 32 reports is a little more than eight. The latest report covers a still relatively modest five cases, involving about 50 chemical professionals.

However, CPR believes it is premature to speculate that such terminations are being phased down. The committee points out it has another 15 as yet unverified mass terminations under investigation. These involve a total of about 250 chemists.

The five terminations covered in the latest report occurred between May 1988 and December 1990. The largest, involving 17 chemists, was at Engelhard. The smallest, involving five chemists, at Kendall. The others were at Upjohn, PQ Corp., and Mead Imaging.

As with previous reports, CPR compared the performance of the

Employer compliance with ACS employment guidelines

These employers provided information	Approximate number of employees separated	Advance notice	Severance pay	Assistance	Employee service	Protection plans
Engelhard Corp. (Edison, N.J.)	17				▨	▨
Kendall Co. (Boston, Mass.)	5					
Mead Imaging (Miamisburg, Ohio)	6		▨		▨	▨
PQ Corp. (Conshohocken, Pa.)	10					
Upjohn (North Haven, Conn.)	11					

☐ Employer met or exceeded guideline standard.

▨ Two or more individuals below guideline standard, but average experience better than "substantially below" criterion.

☐ Employer was substantially below guideline standard, which is defined as follows:

- Advance notice—less than four weeks.
- Severance pay—less than two weeks per year of service.
- Assistance—no assistance rendered.
- Employee service—more than 30% of terminees had 10 or more years of service.
- Protection plans—no continuation of protection plans.

employers involved with termination standards contained in ACS's Professional Employment Guidelines (PEG). Overall compliance was 52%. This compares with an average of 41% for the about 260 terminations covered in all 32 reports. The guidelines cover the involvement of long-service employees, severance pay, assistance in obtaining new employment, extension of protection plans, and advance notice.

PEG states that chemists with a minimum of 10 years' service should not be terminated except for inadequate performance or cause. However, such long-term employees lost their jobs in all five terminations investigated in the latest report, as they did in all but five, or 8%, of the 65 mass terminations investigated by CPR in its last 10 reports dating back to 1986. For the earlier 22 reports, compliance was at a higher 29%.

Compliance with the PEG guideline for severance pay, two weeks for each year of service, is also low. But in this case, it is gradually improving. In the latest report, three of the five employers met it. Since 1986 40% of employers have met this standard. Before that, compliance was only 17%.

The highest compliance is with the standard concerning assistance to terminees in finding new employment. All five firms met it in the latest report. For the past six years it has been met by 85% of employers.

Compliance for the remaining two guidelines falls into a middle range—50% for the extension of health protection plans for a reasonable time after termination, and 40% for a minimum of four weeks of advance notice.

Copies of termination reports as well as of related C&EN articles are available on request from the Office of Professional Services, American Chemical Society, 1155—16th St., N.W., Washington, D.C. 20036.

Michael Heylin

ACS guidelines

Advance notice. Four-week minimum.

Severance pay. Minimum is two weeks per year of service. Additional notice may be given, by mutual agreement, in lieu of severance pay.

Assistance. Efforts should be made to place terminee in another position within the organization, or terminee should be given assistance to find employment elsewhere.

Employee service. Those with minimum of 10 years' service should not be terminated except for continued evidence of previously documented inadequate performance or cause.

Employee protection plans. Should be extended for a minimum of one month, plus two weeks for each year of employee service, following termination, at same rate of contribution as before. Employee would have additional 31-day grace period.

Academic Professional Guidelines approved

The American Chemical Society has put into effect a set of Academic Professional Guidelines that outline some of the obligations and reasonable expectations for individuals in the academic employment environment. The guidelines were recently approved by the ACS Board of Directors at its meeting in New York, following adoption earlier this year in Atlanta by the ACS Council.

Developed by the council's Committee on Professional Relations (CPR), the guidelines specifically address professional relationships among academic faculty, graduate students, and postdoctoral fellows. According to Ramon A. Mount, CPR chairman, the guidelines do not attempt to be comprehensive. Rather, he says, they address some specific situations that the committee believes to be of special concern.

The new academic guidelines are similar in purpose but otherwise separate from the ACS Professional Employment Guidelines (PEG), developed more than 20 years ago by CPR to address industrial employee-employer relationships.

After receiving requests some years ago for guidelines in addition to PEG that addressed academic professional relationships, CPR set up a task force in 1988, chaired by Grace B. Borowitz of Ramapo College of New Jersey, to develop such a set of guidelines. The task force submitted draft guidelines to the council for comment as well as to more than 100 graduate chemistry departments. Responses and comments have been incorporated into the current version just approved.

The ACS Office of Professional Services says it intends to publish the guidelines and distribute them to academic institutions across the nation. Like PEG, the academic guidelines probably will be updated periodically. Following is the entire text of the guidelines as approved by the council and board.

ACS Academic Professional Guidelines

April 1991

Preamble: The Academic Professional Guidelines are intended to provide key guidelines for graduate students, postdoctoral associates, professors, mentors, and academic administrators concerning professional relationships in the academic environment. These guidelines outline some of the obligations and reasonable expectations for individuals as they interact in the unique academic employment environment.

It should be noted that a graduate student or postdoctoral in chemistry generally meets the ACS definition of a chemist and a professional. The term "professor" is employed as a generic term referring to all ranks in the academic research and teaching hierarchy. For brevity, the expression "chemist" or "student" is employed in these guidelines to encompass biochemists, chemical engineers, and others in chemical-related sciences who meet the ACS definition of a chemist.

A. The graduate student and postdoctoral associate—obligations to the professor and to the university.

1. The graduate student or postdoctoral associate should fulfill the responsibilities required by a teaching or research position.

2. The student or postdoctoral associate should maintain honesty, integrity, and diligence in the conduct

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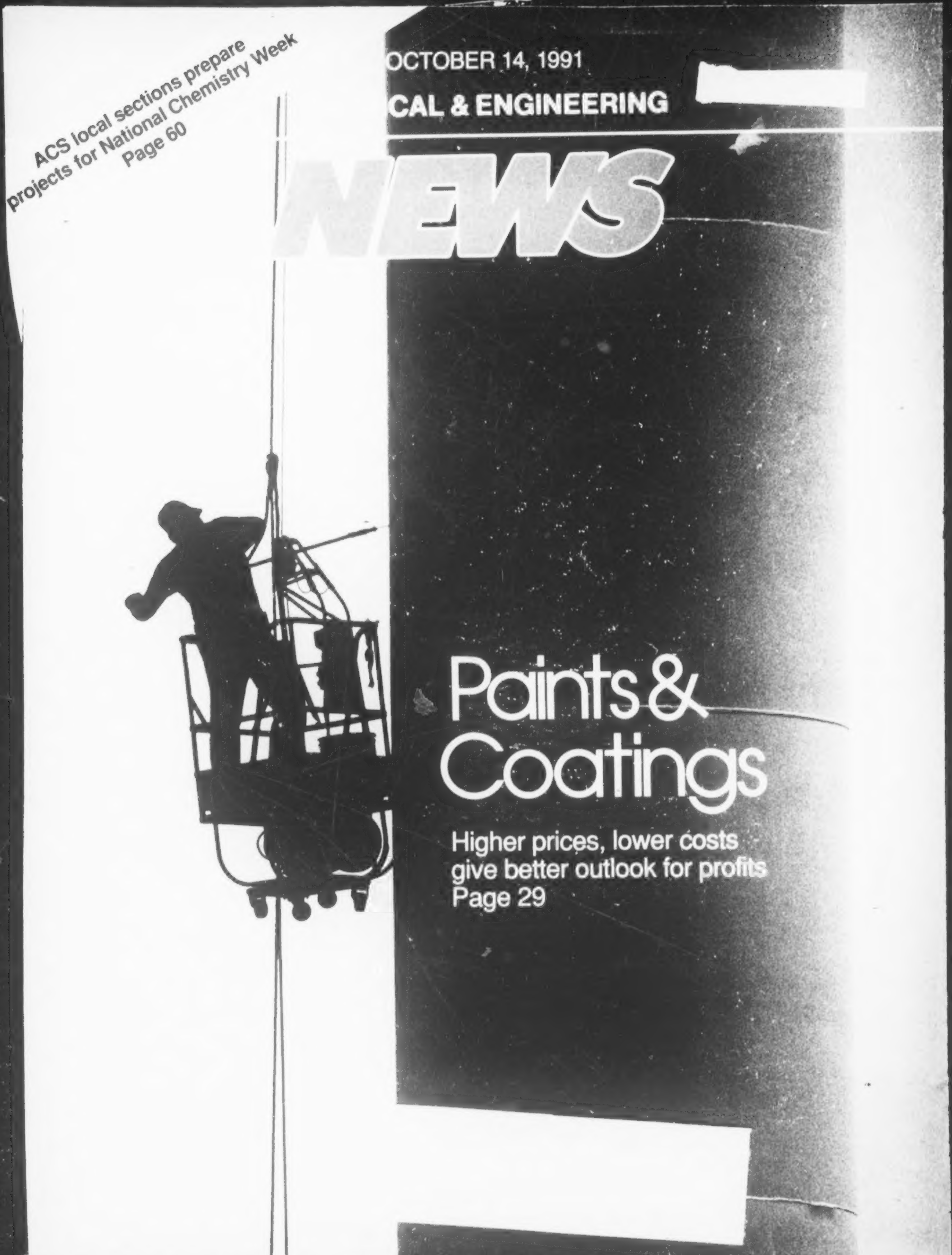

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CHEMICAL & ENGINEERING
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ISSN 0009-2347

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- **Supreme Court refuses to hear suit by Genetics Institute against Amgen over U.S. market rights to erythropoietin, lets stand appeals court decision that benefits Amgen.** Page 5
- **Energy Department draws fire for bypassing Congress in move to start testing underground nuclear waste repository in New Mexico.** Page 5
- **First use of gene therapy to immunize cancer patients against their own tumors began last week at NIH.** Page 6
- **Two prominent scientists—Caltech's Leroy Hood and Rockefeller's Gerald Edelman—will relocate with their labs.** Page 6

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Chemical & Engineering News
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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
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Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Voltammetric pH sensing

This is in reference to our recent report entitled "Molecular Self-Assembly of Two-Terminal Voltammetric Microsensors with Internal Reference" [*Science*, **252**, 688 (1991)] that was featured in Ron Dagani's Science/Technology article (C&EN, May 27, page 24). We wish to point out the earlier conception of voltammetric pH sensing based on the peak potential difference between two electrode-confined redox couples by Israel Rubinstein [*Anal. Chem.*, **56**, 1135 (1984)]. We appreciate Rubinstein's bringing this to our attention.

Mark S. Wrighton
Professor of Chemistry
Massachusetts Institute of Technology
George M. Whitesides
Professor of Chemistry
Harvard University

Chemical distributors

The article "Chemical Distributors Expand Services To Meet Industry Pressure" (C&EN, July 29, page 25) does an excellent job in exploring a host of issues, opportunities, and challenges confronting chemical distributors and the chemical industry.

However, I want to comment on the remarks you quote of a chemical company distributor manager, who asked not to be named, regarding the Responsible Distribution Process the National Association of Chemical Distributors (NACD) is developing for its more than 250 chemical distributor member companies.

NACD developed its own Responsible Distribution Process, rather than signing on to the Chemical Manufacturers Association's Responsible Care initiative, for two important reasons: Our members believed they could not make a commitment to code provisions over which they had no control or which did not apply to them; and the CMA Distribution Code is written for manufacturing distribution and transporters. It is largely nonspecific to chemical distributors.

Wherever and whenever possible, the language of the CMA codes is picked up verbatim in the NACD Responsible Distribution Process. NACD's code-writing committee studied the CMA Distribution Code and applicable portions of its other codes long and hard trying to make a fit before recommending our own Responsible Distribution Process.

In every sense Responsible Distribution will be a stretching process for our chemical distributor members. It will also be more expensive, and for some members with limited resources it may be difficult. NACD is prepared to assist companies with compliance and is writing an implementation guide for this purpose.

The only way Responsible Distribution will make life easier than Responsible Care for distributors is that it covers functions specific to distribution that are not manufacturing functions and are not covered in the CMA codes. In that sense it will be less confusing and frustrating.

NACD certainly wants full and open discussion and constructive criticism of its Responsible Distribution Process.

James M. Doyle
President
National Association of Chemical Distributors, Washington, D.C.

Reformulating gasolines

The negotiated regulatory agreement on reformulated gasoline among various environmental interests, state and local air regulatory agencies, the oil industry, ethanol and methyl *tert*-butyl ether (MTBE) advocates, and the Environmental Protection Agency (C&EN, Aug. 26, page 4) may well prove to be a faustian bargain for all involved. General Motors, Congress, and the Bush Administration also must share blame for mandating the ill-advised use of oxygenates in gasoline as a preferred means of cleaning up our nation's carbon monoxide and ozone air pollution problem areas. The public, its health and economic welfare, will suffer.

The only part of this bargain that will have irrefutable public health and economic benefits is requiring reductions in

Correction

- Sept. 30, page 68: In the Southeast Regional Meeting program, the correct times for Wednesday morning's organic chemistry papers are: no. 228, 8:30; no. 229, 9:20; no. 230, 10:10; and no. 231, 11:00.

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Chemical industry to face increasing challenges in 1990s

Earl V. Anderson,
C&EN Northeast News Bureau

More rapid evolution, ever more "globalization," competition for capital, new technology, and work force—these are only a few of the challenges that lie ahead for the chemical industry as it works its way through the final decade of the 20th century.

During a recent meeting of the Chemical Management & Resources Association at White Sulphur Springs, W.Va., several industry experts jointly painted a vivid picture of what the industry is likely to face in what they call the "new world order." Anchoring the crystal ball was Exxon Chemical's most recent assessment of the industry's long-term outlook—to the year 2000.

C&EN staff photos

Berthiaux (left), Orr: corporate aim—think globally, act locally

Exxon is convinced the chemical industry will undergo a lot of structural change in the 1990s. Some of these changes will occur at the interface between refining and petrochemical operations, says Jean-Francois Berthiaux, an Exxon Chemical vice president.

High on the list of these changes is the reformulation of gasoline, driven by the Clean Air Act. This act requires a minimum oxygen content in gasoline, sets emission standards, and imposes additional restraints that are certain to have an impact on benzene and butane.

The impact of these requirements is compounded by a strong push toward high-efficiency and low-emission vehicles. And the resulting changes in motor fuel, together with a shrinking gasoline market, will significantly affect petroleum economics and operations. That, says Berthiaux, leads to "tremendous" implications for the refinery-chemical plant interface.

The value and availability of various refinery streams will change. The impact will be felt in the supply-demand balance for important chemical feedstocks, such as propylene, isobutane, and aromatics. It is also likely there will be fewer—and smaller—refineries.

The survivors, says Berthiaux, will be very efficient. They will have little spare capacity and very few low-value by-product streams available for chemical upgrading. In fact, he says, refining operations, such as reforming and catalytic cracking, that are very important for chemical operations today, may find that their primary roles in the future will be the "on purpose" production of chemical feedstocks.

However, all is not bleak. Opportunities for new chemical products will open up in the changing transportation and fuel markets. But integrated companies, says Berthiaux, will be in the best position to capitalize on them.

Exxon also believes the gap between petrochemical companies and "traditional" chemical companies will widen. Traditional chemical companies will continue to move away from building-block petrochemicals and their large-volume derivatives. They will intensify their focus on consumer products, advanced materials, pharmaceuticals, biotechnology, and electronics. They will look even more like multitechnology conglomerates than they do today, says Berthiaux.

On the other hand, the successful integrated petrochemical companies will have for parents oil companies that will play a stronger role in the goals, strategies, and priorities of their petrochemical divisions. The mission of petrochemical companies will be to upgrade petroleum feedstock to the maximum. For traditional chemical companies, creating value-added products will be the name of the game.

According to Berthiaux, petrochemical companies will emphasize process technology; chemical companies will put a premium on product technology. As growth slows and competition intensifies during the nineties, all companies will realign their product lines and focus on what they do best.

The industry will continue to be driven by technology, just as it always has been. However, in the product arena, industry leaders will be putting more emphasis on applications and problem solving. In the process field, they will shift to completely new frontiers.

Process technology, for instance, will shift from incremental improvements to totally different approaches—for example, alternate feedstocks to produce derivatives directly and new basic processes, such as separations and selective catalysis. The chemical industry's penchant for innovation shows no sign of letting up, says Berthiaux.

Polyolefins will become more important and a "polyolefins materials industry" will emerge, according to the Exxon analysis. Exxon believes polyolefins will continue to penetrate markets at the expense of other materials.

New catalyst and reactor technologies will produce new olefin monomers and comonomers that will compete with higher priced, high-performance engineering plastics. Single-site catalysts, for instance, may produce these polyolefins for $1.00 per pound or less, Berthiaux says.

Total demand for the chemical industry's products will continue to grow, but that growth will vary by region and by product, he says. "We still see the highest growth rates in the Asia-Pacific region." Demand in North America and Europe will more or less follow gross national product.

However, traditional export markets will disappear because of worldwide overcapacity, putting a crimp in production rates. Olefins is just one example. Philippe Michelon, vice president of SRI International, says the share of olefins capacity held by "new" producers (those outside the U.S., Europe, and Japan) will increase from 24% this past year to 32% in 1997. By the year 2000, he adds, there will be 28 more ethylene producers than there were in 1990.

Increasing pressure to reduce consumption, reuse, reformulate, and recycle could make the market outlook even worse. However, Berthiaux notes the chemical industry always has been able to develop new solutions to problems and to create new products.

Intense competition will mean prolonged periods of low profits in this decade, he adds. Only the largest or second largest companies in each market segment will enjoy a competitive advantage.

Alliances and acquisitions will become increasingly important for chemical companies, according to the analysis. The current industry mind-set leans toward greater emphasis on core businesses. In the upcoming period of slower growth and lower profits, many companies will divest noncore lines and either buy or swap for assets that they need to strengthen their core businesses.

Exxon believes the acquisition wave of the 1980s will continue because companies will see it as a low-cost way to reach their goals without starting from scratch. The number of alliances between chemical companies will rise, as they realize that they can't afford to duplicate existing capabilities. Alliances will provide an inexpensive way to gain new technology and a toehold in markets.

But competition for capital will intensify during the decade, says Berthiaux, as more and more demand falls upon a limited supply. Money will be tight and capital will become more expensive.

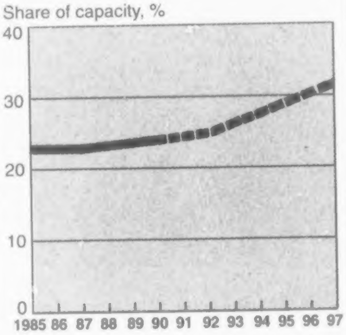
It is expected the chemical industry will have to bear a disproportionate share of this cost because of its large environmental expenditures. It also will have to find alternative ways to finance its projects.

European and Japanese companies, as well as those in the U.S., will attempt to diversify geographically. The key will be to leverage their regional competitive advantages on a worldwide basis.

By 2000, an excess of ethylene producers . . .

	Number of producers		
	1990	2000	% change
Far East (except Japan)	19	36	17%
North America	22	25	3
South & Central America	14	17	3
Africa	3	5	2
Japan	12	13	1
Western Europe	24	24	0
Eastern Europe	9	9	0
Middle East	7	7	0
Oceania	3	3	0
WORLD	113	139	28%

. . . and a big capacity gain for new olefin producers



Note: Olefin producers outside the U.S., Europe, and Japan. Excludes Eastern Europe and China.
Source: SRI International

Companies must learn to "think globally, but act locally," says Berthiaux. There's no ideal model, but he cites setting corporate goals and strategies and developing technology as tasks that should be managed centrally. Operations should be managed at the local level.

Coincidentally, Donald J. Orr, senior vice president for chemicals at Air Products & Chemicals, offers the same advice—"think globally, act locally." Orr says day-to-day business or technical decisions for any foreign market can't be made "while sitting many thousands of miles, multiple time zones, and unique cultures away from the action."

Air Products practices what Orr preaches. More than 25% of its sales are outside the U.S. and its goal is 40% in five years.

Although it produces industrial gases in 25 countries, the company produces chemicals in only three countries outside the U.S. However, Air Products provides both technical service and applications R&D locally. Of the 4000 employees the company has outside the U.S., fewer than 40 are Americans. "We are also very comfortable with joint ventures with local partners," says Orr. Air Products has 10 such ventures in Southeast Asia alone.

Closer to home, one of the most important challenges facing the industry in the 1990s—and beyond—is attracting and retaining the best people. Berthiaux says chemical companies will have a tough job doing so, because they must compete against industries that are perceived to be more "environmentally friendly."

An even bigger problem, says J. Kermit Campbell, Dow Corning's group vice president of U.S. operations, is developing a "world-class" work force out of this country's inadequate educational system. Education at the primary and secondary levels must be reformed, says Campbell.

Math and science achievement levels lag those in many other countries. "That's a tragedy in a technology-driven age," Campbell says. And many students cannot even read or write. That, he adds, is a tragedy in an evolving information age. □

Uniphoto Picture Agency Photo

Higher Paint Sales Brighten Profits Outlook

Marc S. Reisch,
C&EN Northeast News Bureau

Paint makers received a record value for their shipments last year, $11.6 billion, although the total volume of shipments declined more than 6% for the second year in a row to 1 billion gal.

Government statistics show that the value of shipments and cost per gallon of paint sold increased in the three categories into which the government separates data: architectural, product, and special-purpose coatings. Actual shipment volume, however, declined in the largest category, architectural coatings, as well as in the second largest, product coatings.

Manufacturers of radiation-curable coatings—the focus of this year's article—offer their products as a way to eliminate or reduce emissions of volatile organic compounds (VOCs). Moreover, these coatings offer rapid cure on high-speed coating lines.

But whereas radiation-curable coatings are ideally suited for use on production lines, coating of large structures like bridges and large storage tanks in place will not benefit from electron beam and ultraviolet radiation-initiated curing technology. In these cases, uniform exposure to radiation sources is difficult to achieve. However, the inclusion of an aliphatic isocyanate along with an appropriate polyol to create light-stable and chemical-resistant coatings do frequently offer performance advantages. Olin and Hüls plan new U.S. production units and, along with long-time producer Mobay (soon to change its name to Miles), which recently has expanded capacity, these producers may significantly accelerate the growth in aliphatic isocyanate-containing coatings.

As word gets out about the performance advantages of aliphatic isocyanate coatings, existing manufacturers of aromatic isocyanate coatings also may see some growth in the use of their products. This may be true especially when direct exposure to weathering elements is not a factor but when the toughness and chemical resistance that these isocyanates give coatings offer major benefits.

Other factors also will affect the maintenance-coatings market, such as the cost of isocyanate-containing systems versus other maintenance paint formulations, as well as concerns about the health of workers applying isocyanate-containing coatings. As a result, other coating systems are being refined for the maintenance of steel and other industrial structures.

Shipments declined 6% last year

The Persian Gulf War put the brakes on a slowing U.S. economy last year and the paint industry went into a skid. The recession, though, has had some beneficial effects. Raw material costs moderated, and paint companies further cut the cost of doing business by paring back on their payrolls. The breakup of the well-known paint maker DeSoto was largely completed last year (C&EN, Sept. 17, 1990, page 40) and so some of the huge business realignments that occurred during 1990 have not troubled the industry as it attempts to shake off the recession in 1991.

Last year, however, was not a good year for paint shipments. U.S. paint makers shipped just a little more than 1 billion gal of paints and coatings in 1990, down more than 6% from the previous year, according to the most recent data from the Department of Commerce. The result was that industry shipments were almost as low as they were in 1986 when the industry shipped just 987 million gal.

However, the value of industry shipments last year rose 2.5% from 1989 to $11.6 billion. As shipments slipped and prices increased, the average price per gal of paint rose 9.3% to $11.58 in 1990. Manufacturers were able to increase prices at rates greater than the 5.5% rate of inflation for the year. Those increases helped manufacturers in part to recover the increasing costs of raw materials. According to the Department of Commerce, paint material prices in 1990 increased 5.6% from 1989. In 1989, raw material costs rose nearly 12% from the previous year, and the price of paint per gallon rose only 10% to $10.58.

Preliminary 1991 data indicate that paint material costs have moderated even further. Manufacturers report an abundance of titanium dioxide, a key pigment in paints, as new capacity comes on line. The Department of Labor's index of raw material costs indicates that paint material prices actually have decreased nearly 11% between January and August of this year. So the current recession has at least brought the paint industry the benefit of lower raw material costs.

The decline in the cost of raw materials also has given paint formulators some breathing space in the costs they must bear and eventually recover as they formulate their paints to meet increasingly stringent government regulations affecting the emissions of VOCs. As traditional liquid paint formulations dry, organic solvents, which make the paint flow for application, evaporate and can be a component in the formation of atmospheric smog. Paint formulators have had to assume the costs of reformulating their paints or developing new technologies such as powder coatings or radiation-curable coatings to satisfy government limits on VOC emissions that in some categories are as low as 2.8 lb per gal.

Given the available industry statistics, it is difficult to get a solid fix on the profitability of this very large, mature, and diverse industry. For one thing, a significant number of paint operations are themselves part of larger companies, such as Du Pont, BASF, and PPG Industries. The industry also includes a number of large independents, like Sherwin Williams and Valspar, and then a host of small- and medium-sized paint and coatings companies.

The Rauch Guide to the U.S. Paint Industry, produced by Rauch Associates in Bridgewater, N.J., estimates there are 1065 paint companies operating in the U.S. today, 45% of which have fewer than 20 employees. Rauch has the most solid data on industry profitability, but the data are three years old and date from a period when shipments and values grew significantly, raw material price increases were modest, and employment was on the rise. Rauch cites Internal Revenue Service data for 1987–88 from 840 paint and allied products companies reporting total receipts of $10.1 billion and net income of $572 million. These companies' combined profit margin was 5.6% and return on equity 23.2%.

Despite the relief decreasing costs have given the paint industry, the

Three main paint categories break down this way

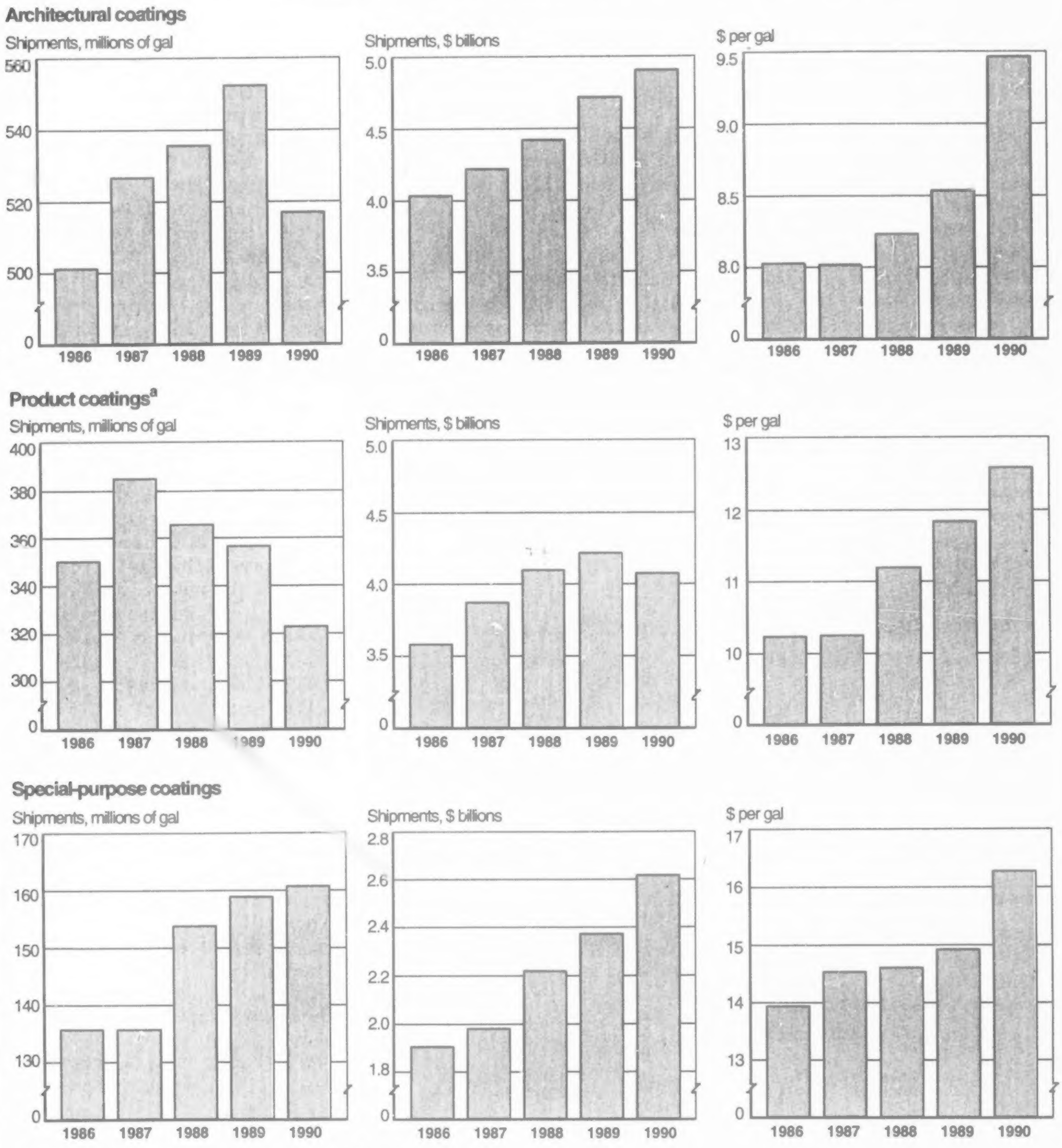
Architectural coatings
- Exterior house paints
- Interior house paints
- Undercoaters, primers & sealers
- Stains

Product coatings[a]
- Wood furniture & fixtures
- Automotive
- Metal containers
- Machinery & equipment
- Factory-finished wood
- Metal furniture & fixtures
- Sheet, strip & coil
- Nonautomotive transportation
- Appliances
- Electrical insulation
- Marine
- Film, paper & foil
- Pipe
- Toys & sporting goods
- Miscellaneous consumer & industrial products

Special-purpose coatings
- Automotive & machinery refinishing
- High-performance maintenance
- Traffic paint
- Roof coatings
- Bridge maintenance
- Aerosols
- Swimming pool coatings
- Arts & crafts
- Metallic coatings
- Multicolored coatings

[a] Original equipment manufacturers. **Source:** SRI International

Shipments up only for special-purpose coatings, but prices rise in all categories



a Original equipment manufacturers. **Source:** Bureau of the Census

recession still has hurt manufacturers. Nalco recently sold its Day-Glo paint business to RPM Inc. of Medina, Ohio, and Ferro and Glidden, a subsidiary of ICI, have formed an alliance in powder coatings. In Europe, DSM is discussing the possibility of swapping its powder-coatings business with Akzo, which would give up its engineering plastics business in the transaction. The transaction, if it takes place, would fill out Akzo's paint portfolio and reinforce its position as one of the largest paint manufacturers worldwide. In another European transaction just completed, Rhône-Poulenc sold its interest in Radcure Specialties, a producer of radiation-curable monomers and oligomers, to the Belgian company UCB. Radcure has substantial U.S. operations managed from its U.S. headquarters in Atlanta.

A 1990 survey of the paint and

coatings industry based on Bureau of Census figures shows that architectural coatings, which include paints applied both to interior and exterior surfaces, made up slightly more than half of all paints shipped in the U.S. Product coatings for the original equipment market, which includes automotive and appliance coatings, account for some 32% of U.S. paint volume. And special-purpose coatings make up the remaining 16% or so of total paint shipments. This category includes large-volume maintenance items, automotive refinishing, and coil coatings.

Shipments of architectural coatings in 1990 declined 6.3% from the previous year to 517 million gal. The value of those shipments, however, rose 4% to $4.91 billion last year, and the unit price per gallon rose 11% to $9.47. The recession, in combination with a continuing lag in new housing starts, did have a negative impact on these coatings. However, shipments of architectural coatings as a percentage of the overall paint market remained the same in both 1990 and 1989, and they even increased over the 51% share these coatings had in 1988 when more gallons were shipped.

Product shipments last year for the original equipment sector fell 9.5% from 1989 to 324 million gal. The value of shipments also declined, slipping 3.8% to $4.08 billion. Unit price per gallon increased 6.3% to $12.59. Despite the actual slowdown in shipments, costs continued to rise in this category. Paint makers sought to recover both the costs of raw material increases in previous years and the costs related to reformulating to meet ever-increasing VOCs limits.

For special-purpose coatings, according to the government figures, 1990 shipments increased 1.3% from 1989 to 161 million gal. The value of those shipments rose 11% to $2.62 billion, and the unit price per gallon increased 9.1% to $16.27. The relatively good performance of this product sector may be attributed to the recession. Plant and equipment idled during the recession is frequently refurbished or maintained for use when the economy picks up again. Also, bridges and other outdoor structures that are overseen by local or federal governments still must receive regular maintenance. Those costs are usually deferred only during a prolonged and severe slowdown when tax receipts fall off precipitously.

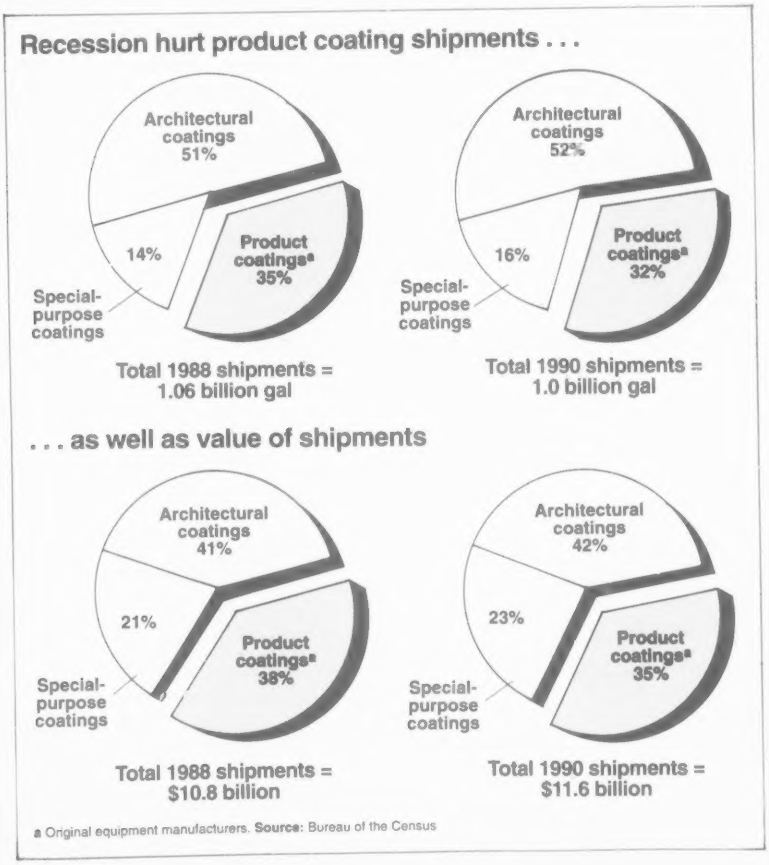
According to the Department of Labor, indexes covering both paint materials and prepared paint prices show radical changes during the first eight months of 1991. In that period, the price index for paint materials declined a surprising 11% to 134.8 (1982 = 100). In 1990 the index rose 5.5% from 1989, following a 12% annual increase in 1989. If the trend for this year continues, 1991 will have been the first year to show a material prices decline since at least 1975.

The Department of Labor's index for prepared paint prices dropped 1.4% in the first eight months of 1991 to an index of 130.1. If this trend is sustained for the year, it also will mark the first year to register a decline since at least 1975.

On an average annual basis, paint material costs increased only 5.8% between 1975 and 1990. Prepared paint prices rose 4.6%. This continues to be an industry that depends overall on factors other than price increases to maintain profitability. Where price increases barely keep pace with inflation, manufacturers continue to survive by gaining market share, buying market share, and improving manufacturing efficiencies.

Whereas the Bureau of the Census reports shipment declines in 1990, the Department of Labor emphasizes the drop in total employment. The number of production and nonproduction paint industry workers declined 1.1% to 61,800 compared with a revised 62,500 for 1989. In 1984, when the industry employed 62,000 people, manufacturers produced 32 million fewer gallons of paint. Productivity for this industry has increased.

The number of nonproduction employees of paint firms declined


Recession hurt product coating shipments . . .

. . . as well as value of shipments

[a] Original equipment manufacturers. **Source**: Bureau of the Census

4.4% in 1990 to 30,500; production employees decreased 1.1% to 31,300. Between 1981 and 1990, employment of production employees was unchanged. The level of nonproduction employees during the same period of time declined 5%.

Radiation-curable coatings poised for growth

Coatings that are cured almost instantly upon exposure to either electron beam (EB) or ultraviolet (UV) radiation are poised for growth in the world market. They offer a number of advantages in addition to rapid cure rate on assembly lines. The radiation equipment required takes up considerably less space than curing ovens and can coat heat-sensitive materials. The result is, in many cases, 100% solids VOC-free coatings. Costs of these coatings tend to be competitive with other paint systems at $15 to $100 a gal.

The term "radiation curing" may cause some misunderstanding. It does not mean that coated materials are exposed to radioactive emissions. It does, however, mean that the photons that UV light generates or accelerated electrons from an EB processor can initiate cure in these specially formulated coatings.

Suppliers to the U.S. market estimate the growth rate of radiation-curable coatings at 10 to 15% a year. According to estimates published by consultants Anthony Berejka of Ionicorp, Cold Spring Harbor, N.Y., and William Radak, R&D Coatings, Wexford, Pa., the value of radiation-curable coatings was $110 million in 1989. Their estimates, published in *RadTech Report*, the journal of Radtech International North America, a Northbrook, Ill.-based trade association for radiation technology, break down principal applications by plastics, the largest use, followed by wood, paper, metal, and miscellaneous. The two consultants estimate the market at $250 million for all radiation-curable material uses including coatings, electronics, inks, and adhesives.

Rauch Associates also estimates the size of the market at $250 million, with 10 million gal of coatings without solvents shipped in 1989. Rauch cites major uses on flatstock-fillers in particle board and hardwood flooring, protective coatings for cans, high-gloss no-wax coatings for floor tiles, and wood finishes. Like powder coatings, radiation-curable coatings offer paint applicators for the original equipment market a new technology to both speed up processing and reduce waste and VOC output. Unlike powder coatings, with sales in excess of 100 million lb annually (C&EN, Sept. 17, 1990, page 58), radiation-curable coatings are only beginning to establish themselves in the market now, though they have been under development for at least two decades.

Ionicorp's Berejka, who is also president of Radtech, believes that radiation curing of wood and plastic

Problems.

Fusion Systems technician monitors plastic bottles entering UV curing chamber

coatings offers a way around the VOC issue. Adoption of UV and EB curing systems allows compliance with the 1990 Clean Air Act without the investment in solvent recovery systems, says Berejka. And since radiation cures without high-temperature exposure, it is ideal for curing plastic components. The technology is not cheaper, he says, just more cost-effective. Where unit sales are concerned, radiation-curable coatings are high cost because they are still low-volume materials. Berejka sees prices coming down as volume increases.

R&D Coating's Don Eshenbaugh says sales of radiation-curable coatings began in the mid-1980s, though development of systems for inks and coated printing stock in graphic arts began in the early 1970s. He predicts that with all the interest in radiation-curable coatings now, a sharp upturn in their growth will occur beginning in 1995. Though most users think of radiation-cur-

Solutions.

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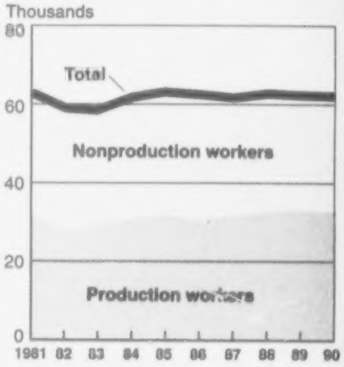
able coatings as primarily suitable for production line coatings of flat stock, curing of three-dimensional objects is possible. Properly designed equipment can expose all parts of a product to light, he notes.

According to Bob Sweetman, engineering director for Fusion Systems, a privately held manufacturer of UV lamp systems in Rockville, Md., the push to lower VOC emissions has motivated much of the switch to radiation-curable coatings. Sweetman describes his company as a market leader in the manufacture and sale of UV equipment. Fusion Systems invented and developed long-life electrodeless lamps that will outlast traditional tungsten arc lamps, he says.

Fusion takes a modular approach to the lamp systems it assembles for its customers, says Sweetman. The company assembles lamp modules to suit customers' process requirements. Startup costs for UV systems range from $4200 to $200,000 for the largest system. That contrasts with EB curing systems that cost anywhere from $750,000 to $1 million, says Sweetman. Electron beam curing is justifiable only when very high speed systems are required or when UV beams cannot penetrate. Electron beam systems are also frequently installed when nitrogen atmospheres are required for a more complete cure. That inevitably adds to the cost of the system as well.

UV systems now can cure pigmented coatings. In the past, mercury vapor arc lamps could not cure pigmented coatings because they only produced UV light at the lower end of the spectrum. Sweetman claims that Fusion Systems' latest lamp system can cure heavily pigmented white coatings up to 200 μm thick on wood substrates. Formerly, only EB systems could cure that type of coating. Still, he cautions, heavily pigmented thick coatings will not cure well under UV light. Although the company's system frequently cures clear coats as thick as 0.1 inch, it will not be able to cure heavily pigmented coatings of the same thickness.

Employment has slipped in paint industry

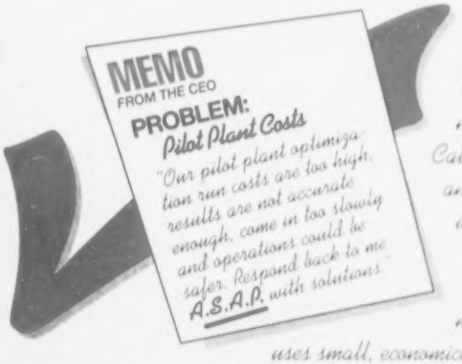


Source: Department of Labor

Aetek, another manufacturer of UV lamp systems, estimates that UV systems cost about half of what EB systems cost. Mark Gilmour, sales representative for Aetek, Plainfield, Ill., says heavily pigmented coatings often cure better with EBs. In some wood applications, Aetek may install its lamps in a line with another manufacturer's EB equipment. In these hybrid systems, UV will help the coating to "flow out" while the EBs bring the coating to a full cure, says Gilmour.

Flat materials and rotating convex surfaces cure best because they can be directly exposed to sources of UV light. Aetek claims clear coats exposed to a lamp delivering 400 watts per inch can cure plastics at a rate of 300 feet per minute, metal at 200 feet per minute, and wood at 25 feet per minute. In addition to lamp lines for decorative metal, fiber-optic, and auto lamp reflector coatings, Aetek installs custom wide-lamp lines to cure clear coats on no-wax flooring. Gilmour says the flooring systems require highly specialized lines that, unlike most UV systems, make use of nitrogen atmospheres to exclude oxygen for better finishes.

Where Aetek does install its lamps in a hybrid system, it frequently does so with RPC, Hayward, Calif. RPC, which formerly owned Aetek and which is now majority owned



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by Japan-based Sumitomo Heavy Industries, sold its Aetek division to Geo International Corp., Stamford, Conn., in 1988. According to David A. Meskan, vice president of marketing for RPC, UV and EB technologies are really not competitive. They only overlap in a small area. Electron beams, he notes, are superior in penetrating opaque coatings. For instance, on printed wood-grain finish papers, the beams penetrate the top coat, the paper, and the adhesive that laminates the paper to a surface all in one pass.

EB equipment is also much more expensive than UV equipment. A basic EB system costs about $600,000, says Meskan. A big system may approach $2 million, whereas most systems installed today approach $1 million. However, they offer higher productivity and more energy efficiency than either UV cure or more traditional oven-baked cure, claims Meskan. The company's fastest line is installed on a 130-inch-wide web that moves material for cure at 1000 feet per minute, he says. Meskan concedes that UV-curing applications are 50 to 100 times more energy efficient than oven curing. However, EBs cure coatings with an efficiency five to 10 times greater than UV curing, he says.

Other advantages EB curing makes possible are coatings without expensive photoinitiators that are required for UV cures; no-shrink coatings because the 100% solids coatings do not contain solvents that must be evaporated; and EB-cured coatings because they provide good mechanical properties such ~~as high-gloss~~ and good abrasion resistance, says Meskan.

Over the past five years, the biggest push in EB systems has been on web printing presses to cure coated paper stock and printing inks. However, says Meskan, during the past 18 to 24 months, wood furniture makers have become very interested in EB-cured flat stock to speed the production of ready-to-assemble furniture. A few have begun to install EB lines, he says.

U.S. customers, says Meskan, are making greater use of EB systems than their counterparts in either Europe or Japan. Although Europeans may be ahead in the use of UV cure, the U.S. leads in EB technology and installation. And he adds that the U.S. leads Japan in the use of EB equipment. The Japanese are just moving to order EB production equipment at this time.

German-based Henkel has headquartered its radiation-curable materials business in the U.S. According to Robert Lieberman, a business director for Henkel Coatings & Inks, all new product synthesis and research and development for radiation-curable coatings is based in Ambler, Pa. The company supplies industry formulators with three major components for radiation-curable coatings: low-molecular-weight monomers, oligomers, and photoinitiators. Whereas Henkel manufactures the first two types of components, it has been a nonexclusive distributor for Velsicol Chemical's line of photoinitiators since August. With the conclusion of its distribution agreement with Velsicol, Lieberman says Henkel is now a one-stop shop for radiation curable raw materials.

Lieberman believes the radiation-curable coatings market will grow 10% per year for at least the next five years. In support of that growth, Henkel has introduced a half dozen new monomers within the past year, he says. Most recently, the company has introduced a new line of reactive acrylate monomers to be sold under the Photomer 8000 series tradename. They are methoxy ether acrylates, which yield improved reactivity, film, and adhesion properties compared with other commercially available monofunctional acrylates and are competitively priced, says Lieberman.

Improved reactivity is an important goal at Henkel, he notes. The objective is to come up with material that will cure fully under normal atmospheric conditions. In that case, the inert nitrogen atmospheres that are now often required for cure with EB-curable coatings would be unnecessary. The current line of mono-

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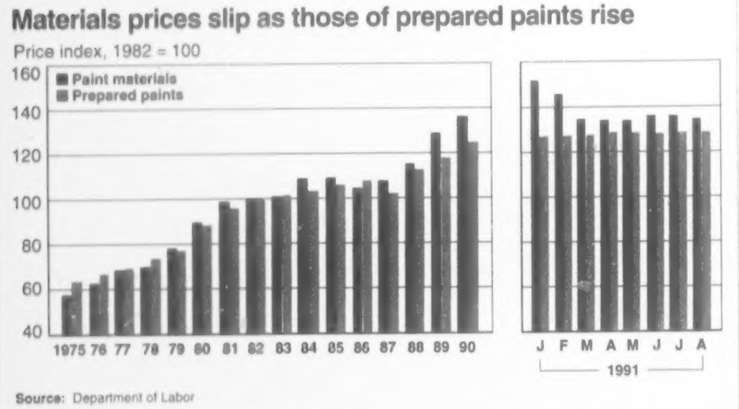
Materials prices slip as those of prepared paints rise



Source: Department of Labor

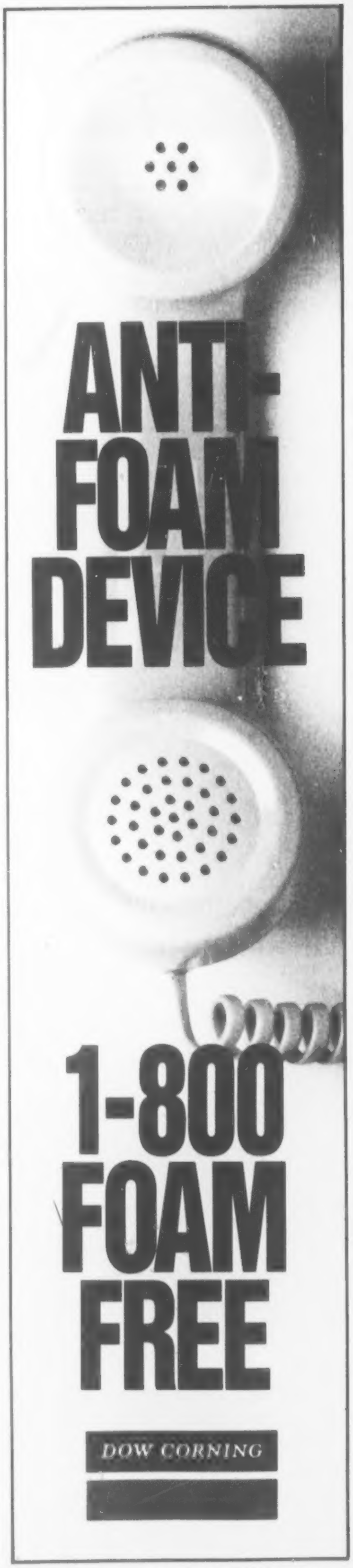
mers and oligomers includes mono-, di-, and trifunctional acrylates; amine acrylates; epoxy acrylates; polyester acrylates; and urethane acrylates.

Lieberman acknowledges concern within the radiation-curable coatings industry over skin and eye irritation caused by acrylate materials. In 1987 suppliers and users teamed up to organize the Specialty Acrylates/Methacrylates Panel (SAMP) under the Chemical Self-Funded Advocacy & Research Division of the Chemical Manufacturers Association to test the toxicity of the acrylates, he points out. Additionally, Henkel is developing nonacrylate backbones for its line of monomers and oligomers to remove concern over acrylate toxicity. However, none are yet commercially available, he says.

According to SAMP manager Marian Stanley, the group has started a voluntary research program testing acrylates and methacrylates to gain knowledge and toxicity information about the materials. These are not strictly radiation-curable materials, but include those with other uses. Companies funding the program include Hüls, 3M, Rohm & Haas, Du Pont, Dow Chemical, PPG, Union Carbide, and Lubrizol. Although the group hopes to show lower toxicity for the materials than is now believed, not enough testing has been done to date to prove that assertion, says Stanley.

Paul C. Nelson, manager of environmental health and safety affairs for Radcure Specialties, Atlanta, and first chairman of SAMP, says the panel was formed to resolve issues surrounding Environmental Protection Agency regulations affecting the introduction of acrylates into the market. The materials are suspected skin carcinogens, he says. Test programs now under way in consultation with EPA are meant to evaluate current regulations. A preliminary benefit of testing already completed was EPA's agreement to modify use rules for low-molecular-weight acrylates. As a result, labeling on material safety data sheets has been revised "more in line with what you'd expect under OSHA regulations," says Nelson. Still, all manufacturers of these materials recommend that people working with them wear safety glasses or eye goggles and impervious gloves to avoid all eye and skin contact, he says.

International Specialty Products (ISP), Wayne, N.J., once known as GAF Chemicals but now a publicly traded company, has developed a family of radiation-curable materials without the toxicity problems associated with acrylates. Three vinyl ethers that have low-toxicity profiles have been introduced to the market under the Rapi-Cure tradename, according to Jeff Plotkin, ISP market manager. Two of the vinyl ethers, one a triethylene glycol divinyl ether and the other a cyclohexanedimethanol divinyl ether, are difunctional reactive diluents that can be used in place of acrylates, he says. The third one, a hydroxybutyl vinyl ether, can be used either as a reactive diluent or as an intermediate to produce vinyl ether-containing oligomers.



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Plotkin says ISP is working on a range of mono-, di-, and trifunctional vinyl ethers to allow formulators more latitude. The main advantage of vinyl ethers is that they offer formulating versatility, he says. Because of their solvating properties, ISP is hoping to develop sprayable wood coatings approaching 100% solids. This advance will allow furniture makers to spray intricately designed furniture with low or no VOCs. Of course, these advances do carry a higher price tag. Plotkin says that vinyl ether-containing systems will cost 10 to 15% more than comparable acrylate systems.

According to Jim Reese, vice president of marketing for DSM Desotech, Elgin, Ill., the vinyl ethers are safer to handle than the acrylates since they are less likely to be skin sensitizers. Some of the vinyl ethers are not even eye irritants. In addition, they are low odor materials, unlike the acrylates whose odor can be offensive, he notes. DSM Desotech uses GAF's vinyl ethers to manufacture vinyl ether maleates, which are sold to paint formulators. The company, formerly owned by DeSoto but now owned by Dutch chemical company DSM, also manufactures acrylate oligomers. Reese says the company's Desolite and Cableite materials dominate the market for telecommunications resin systems.

The market for radiation-curable materials, Reese adds, has grown 12 to 15% annually over the past five years, though some markets, such as telecommunications optical fiber and cable coatings, have grown faster. He projects yearly growth of 10 to 15% for the radiation-curables market over the next five years, particularly in markets for which the low- or no-solvent characteristics of the technology offer a benefit. He sees promising growth in the market for sprayable vinyl ether-modified coatings on wood.

Radcure, a manufacturer of radiation-curable monomers, oligomers, and specialty photoinitiators, offers a variety of acrylate-based systems. The company, says a spokesman, is involved in a number of developmental research projects, but declines to be more specific. Radcure was created as a unit of Celanese and was subsequently bought by RTZ Chemicals. RTZ linked up with Belgium's UCB to further develop radiation-curable monomers and oligomers. Rhône-Poulenc bought RTZ, thereby gaining an interest in what became Radcure in 1989. UCB subsequently operated Radcure and early last month reached an agreement with Rhône-Poulenc to acquire all shares of Radcure, though no financial details have been disclosed.

A major supplier of pigment systems and additives for radiation-curable coatings is Ciba-Geigy. Although it supplies a relatively modest amount of antioxidants, light stabilizers, and optical brighteners for radiation curables, the company's major additives emphasis is photoinitiators for UV-curable coatings. According to Andrew Mar, business director of additives for radiation curing, radiation curable coatings are growing at a rate of 10 to 15% a year in the U.S., 15 to 20% in Japan and Europe (higher, albeit from a lower base). The principal attraction in Japan and Europe is the space savings UV cure systems offer over oven cure lines. In addition, energy costs are higher in Europe and Japan than they are in the U.S., thus giving an additional boost to UV-curable coatings.

Mar believes that another boost to the growth of UV curables will come around 1994 or 1995 when EPA rules affecting VOC emissions from wood and plastic coatings will spur coatings users to convert to a low- or no-VOC alternative like UV-curable coatings. Other alternatives for wood and plastics may be waterborne coatings and high-solids solvent coatings.

In trying to anticipate market needs, Ciba-Geigy has offered a variety of photoinitiators, many developed in concert with lamp manufacturers like Fusion and Aetek as well as monomer and oligomer suppliers, says Mar. Ciba-Geigy introduced its first photoinitiator 16 years ago—Irgacure 651, a 2,2-dimethyl-2-phenyl

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acetophenone that still has broad use, he says. However, because Irgacure 651 is activated by UV radiation that some pigments absorb, Ciba-Geigy has introduced other photoinitiators—such as Irgacure 369, an acetophenone-class photoinitiator—that allows more pigment loading in a coating without cutting down on the UV-induced cure of a coating.

At $39 per lb for Irgacure 369, Mar is aware that the photoinitiator is the most expensive component in a radiation-curing formulation. However, he notes, the manufacture of Irgacure 369 requires a seven-step synthesis and, although it is incorporated into a coatings formulation at 1 to 3% by weight, it is not quite so expensive on a unit basis and offers good value. In fact, UV cure would be impossible without the use of a photoinitiator, he points out.

Ciba-Giegy's most recent photoinitiator is its Irgacure 784, a titanocene photoinitiator that absorbs longer wavelength light. As a result, the UV source can be designed so that it poses less danger for eye damage, says Mar. Another recent introduction is Irgacure 261, a ferrocene-based photoinitiator recommended for epoxy ethers only. Mar says it is Ciba-Geigy's first cationic photoinitiator. (Cationic photoinitiator competitors include 3M and Carbide.)

Borden, a formulator of radiation-curable coatings, sees double-digit growth ahead, says Camille J. Kallendorf, commercial development manager for Borden's packaging and industrial products division. Emerging growth areas in particular are coatings for plastics, automotive components, and stereo lithography. The latter is a system developed to manufacture three-dimensional computer-controlled models using UV-cured material. The system allows engineers to make parts prototypes.

Kallendorf says Borden custom-manufactures two basic types of systems for the market—acrylates and epoxy cationics. Although she acknowledges that the acrylate systems are skin sensitizers, the problem is not so significant now as it once was. Formulators, she says, have come up with less irritating formulations, and industry practices in handling have been improved. The epoxy cationic curing systems, she says, are easily handled and are not significant skin sensitizers.

Leigh Quinn Jr., vice president of sales for QureTech, a Seabrook, N.H., division of paint resin maker K. J. Quinn, says the radiation-curable coatings are reliable because once the system is put into place, it works regardless of moisture in the air or other environmental variables. Once the formulation is set, and the radiation source is in place, maintenance is minimal. A production line can start up at the same performance level at which it was shut down, he says.

QureTech supplies fully formulated 100%-solids, specialty UV- and EB-curable acrylate coatings. They are custom designed to fit a manufacturer's requirements, and, in doing so, QureTech works closely with radiation source suppliers. Many materials suppliers and formulators are predicting rapid growth over the next few years, but Quinn is cautious. He expects mixed results for radiation-curable coatings over the next few years because of the current weak economy. Still, he agrees that radiation-curable coatings opportunities exist and in the long run will grow.

Isocyanate capacity grows as do coatings uses

Whereas radiation-curable coatings offer performance advantages on production lines, isocyanate-containing coatings make for more durable, abrasion-resistant paints and coatings. Systems that incorporate aliphatic isocyanates also offer good weatherability and are in increasing demand for such exterior applications as bridges, storage tanks, and process industry plants where outstanding chemical resistance is a requirement.

The number of aliphatic isocyanate suppliers has grown over the past few years in response to the demand for systems incorporating aliphatic isocyanates. Both Hüls and

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clude powder coatings and UV-curing resins, notes Cullen. For UV-curing systems, the isocyanate is incorporated as part of an oligomer or other resinous material, giving the resultant UV-cured system good performance characteristics. In particular, the urethane linkage gives excellent abrasion resistance, a reason, says Cullen, for its use in UV-cured hardwood floor clear coats.

Hüls will soon complete the construction of an isophorone diisocyanate (IPDI) unit as part of a larger $100 million project at its plant near Mobile, Ala. Until now, Hüls had been supplying customers with IPDI imported from its facility in Germany. According to Henry A. Kasprzak, general manager of the coatings raw material group at Hüls, the Mobile plant probably will be on stream during the first quarter of 1992. Though he declines to say what the unit's IPDI capacity will be, he comments that "availability will not be a problem" once the plant begins regular production.

Along with the domestic production of IPDI and derivative polyisocyanates, Kasprzak says Hüls is prepared to offer coatings manufacturers more extensive coatings support from recently enlarged labs in the company's Piscataway, N.J., technical center for liquid coatings and in Mobile for powder coatings. IPDI, adds Kasprzak, is particularly suited for use in VOC-compliant coatings because of the low viscosity of the material.

Kasprzak believes that overall growth of the aliphatic isocyanates market is 8% per year, with faster growth of 10% annually for isocyanate-containing powder coatings. These figures may not be as reliable for 1991, because the economy has slowed somewhat this year, he says. Hüls sells its IPDI-derived materials under the names of Vestnat for the monomer and Vesticoat for the trimer and converted products.

Though the isocyanate-containing materials offer excellent performance characteristics, Kasprzak notes that isocyanates are hazardous materials. Hüls supplies a great deal of information to customers on the safe use and handling of its materials, as do other isocyanate producers. However, he notes that because IPDI is not as volatile as some other isocyanates, it is easier to handle than they are.

Olin also plans to start up a new aliphatic isocyanates plant in Lake Charles, La. According to Tony Hamer, general manager of the performance urethanes business, the new plant probably will be completed by Feb. 1. The company expects to begin shipments of product during the second quarter, but not all products will be available immediately, he says.

Plant capacity hasn't been disclosed, though it is a "multiproduct unit" whose ultimate capacity will depend on the product mix of HDI, IPDI, and hydrogenated MDI to be produced at the site. Cost of the new unit also has not been revealed. Customers are receiving development quantities from a pilot plant also located in Lake Charles, he says.

Olin sees itself as an alternate supplier able to give formulators a choice: Olin or Hüls for IPDI, Olin or Mobay for hydrogenated MDI and HDI. Hamer notes that Olin also sells an aromatic isocyanate, toluene diisocyanate (TDI). It has many uses such as in foam products, but may also be used in coatings such as on interior wood where light stability is not an important asset, he says.

Spurring use of aliphatic isocyanates is the fact that the urethane formulas in which they are a component can be made into high-solids coatings and thus are low in VOCs. Hamer sees opportunities for Olin's aliphatic isocyanates in both the coatings and elastomers markets. He says the new plant coming on stream in Lake Charles is similar to the Mobay and Hüls units, but that Olin's labs are working to bring products on stream that will be unique, differentiated products.

"Our approach will be to work with customers and customize formulations for them," he says. As for its raw material, Olin will supply Du Pont with diamines. Hamer notes

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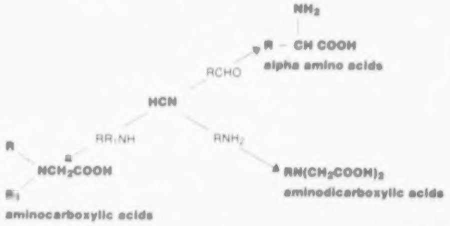

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that Du Pont and Olin have traditionally had a close working relationship. Du Pont is also a major user of aliphatic isocyanates in the coatings it supplies to the automotive and maintenance coatings market, he notes. W. R. Grace will be Olin's source for nitrile ingredients, and isophorone is available on the merchant market. Olin will offer customers applications and technical service help from its research facility in Cheshire, Conn., he adds.

American Cyanamid opened a commercial facility to produce *m*-tetramethyl xylylene diisocyanate (TMXDI) and dimethyl *m*-isopropenyl benzyl isocyanate (TMI) in late 1987. Capacity figures for the unit have not been disclosed, says Jim Druzbacky, coatings business manager for the urethane chemicals department.

Druzbacky says the Cyanamid products are doing well in the market as relative newcomers. He does not expect them to compete head to head with the other aliphatic isocyanates, because Cyanamid believes they are specialty isocyanates that will fit in high-performance niches. They are not "me too drop-ins for IPDI or MDI," says Druzbacky. He adds that "we are looking for value-added niches where our products can command a higher price for their performance characteristics." Those include automotive and other original equipment markets, auto refinishing markets, and maintenance coatings, plastic coatings, and industrial metal coatings.

TMXDI has just been introduced in a water-based urethane dispersion under the Cydrothane tradename, he says. Cydrothane can be formulated into a coating with good film properties, hardness, toughness, and 0.1 lb-per-gal VOC content, without the use of organic cosolvents, Druzbacky says. Another Cyanamid polyisocyanate resin, Cythane 3160 based on TMXDI, is aimed at automotive coatings as well as plastic, coil, and electrodeposition coatings, where the flexibility and toughness the material offers is an advantage.

Druzbacky says that TMXDI-based materials also offer minimal safety risks. Tests to date show that such materials are not pulmonary sensitizers, says Druzbacky, though studies to determine toxicity are still ongoing. Cyanamid still recommends that the materials be treated as hazardous and recommends that skin contact be avoided and users wear respirators.

Industrial maintenance coatings flat in 1991

Aliphatic isocyanates are a major component in high-performance maintenance coatings, and may help refuel a resurgence in this steady but rather dormant market. According to Jay Willner, a consultant in San Francisco with WEH Corp., sales of maintenance coatings amount to about $1 billion annually. About 45 million gal of paints go into this market, which includes coatings for petrochemical and petroleum plants, water and waste treatment plants, electric and gas utilities, bridges and highways, offshore oil and gas platforms, aircraft, and farms.

Willner characterizes 1990 as a relatively good year, but he finds that 1991 is not turning out so well. A bright spot over the next five years, however, is expected to be coatings to maintain structures that contain leaks around storage containers. He projects that that market, valued at $80 million in 1991, will grow 10% per year to $130 million by 1996.

Formulators in the maintenance market number more than 100 with the 10 largest suppliers holding 71% of the market in 1990, up from 55% in 1984, and the five largest holding 46%, up from 34%. Following the consolidations of the past few years that include the ICI purchase of Glidden, Valspar's purchase of Mobil's paint business, and Courtaulds' purchase of Porter Paints, Willner doesn't expect this industry to concentrate further. Any large company that purchases any of the numerous small specialists in the business would only add between $2 million and $5 million in sales to its portfolio, says Willner.

According to Jack J. Bracco, coatings division market development manager at Mobay, the push to lower VOC limits also has affected this market. With government rules lowering VOC limits to 2.8 lb per gal in 1994, Mobay has come out with lower viscosity acrylic polyols to meet the market's needs, he says. Research in polyol technology along with work on waterborne polyurethane dispersions probably will allow isocyanate-containing coatings to maintain their edge over alkyds, Bracco believes.

Mobay photo

Worker applies high-performance polyurethane coating to steel tank

Bracco is worried that as allowable VOC contents are pushed lower, coatings may not perform so well. A problem with one-component waterborne polyurethane dispersions is that they are difficult to apply under very humid conditions and in inclement weather like all waterborne systems. The question now is, he says, "How low can we go in VOCs with polyurethane dispersions and still get good performance?" Coatings usually fail because they are improperly mixed or applied over frost, dirt, or grease. Higher solvent-containing coatings give a margin of latitude, but waterborne coatings require "supercritical clean surfaces to get good adhesion," he says.

To get those supercritical clean surfaces will require blasting of structures, and removal of the old paint, greases, and oils that will pose more than just a simple disposal headache. Blasting will loosen much old lead paint that will have to be removed carefully and disposed of properly. Current polyurethane coatings systems may cover the lead paints and put off, at least for now, the disposal of the old lead-containing coatings, he says. Where removal of lead paint can be postponed, Bracco recommends a moisture-cured polyurethane spot primer containing Desmodur E-21, followed by a two-component aliphatic polyurethane intermediate and top coat over the entire structure.

Du Pont's Maintenance Paint Service (MPS) tries not to remove lead-containing coatings unless they are about to fail, says James T. Kimball, director of maintenance finishes. Du Pont's current line of coatings, including urethanes, epoxies, and alkyds, are heavy metal-free, he says. MPS prefers to do spot repairs where lead coatings may be failing so as to lower the annual costs to its customers, whose facilities include petrochemical and refining plants as well as some bridges. It formulates coatings based on it own raw materials as well as materials it buys from outside suppliers.

In maintaining a customer's facility, Du Pont prefers to brush and roll on coatings rather than spray coating to reduce exposure to the applicator as well as plant workers nearby. It is also developing isocyanate-free coatings that promise the same performance as isocyanate-containing coatings, says Kimball. It recently developed a new medium solids resin system based on polyacryl anhydride that it believes will perform as well as urethane coatings.

Because worker safety in applying coatings on maintenance structures is an issue, and because of the critical preparation necessary for repainting any large steel structure, the Steel Structure Painting Council (SSPC), Pittsburgh, Pa., has set up a certification program for applications contractors. The nonprofit organization has 650 individual and 400 company members from businesses including painting contractors, facility owners, coatings manufacturers and distributors, applications equipment suppliers, and industrial hygienists.

Bernard R. Appleman, SSPC executive director, says that his group is working to "professionalize" the industrial coatings industry. One step in that direction has been a paint contractors certification program that evaluates the contractor against the SSPC's safety, quality control, technical capability, and management procedures standards. SSPC hires an independent evaluator who does a thorough inspection, including field inspection of a contractor, says Appleman. The contractor pays for the evaluation. SSPC certifies those who get a passing grade. The program requires annual reevaluation in areas in which the contractor may have been weak, says Appleman.

Of the 1500 or more contractors performing industrial painting of steel structure in the U.S., Appleman says his program has certified about 23. He hopes more will enter the program in time. SSPC is encouraging facility owners to require that contractors have certification before they are allowed to bid on a project, he says. "It is important not to go just for the lowest bid, but for the lowest qualified bid." Appleman believes that some facility owners do not monitor the safety of their contractors as closely as they monitor their own personnel. This certification program will go the extra step in ensuring that at least painting contractors will handle their job according to safe procedures.

Appleman thinks suppliers of two-component urethane systems have done a good job of communicating relative risks of applying isocyanate-containing coatings. A few facility owners have refrained from using two-component systems because they have a no-risk mentality, he says. "I don't think you can operate with no risk." He does applaud the greater general awareness of safety issues, however, and cautions that the industry will have to pay greater attention to dealing properly with lead paint removal in preparation for repainting.

Not all structures that need maintenance are constructed of steel. Concrete can degrade under exposure to harsh environments. Texaco Chemical, Houston, Tex., says it has

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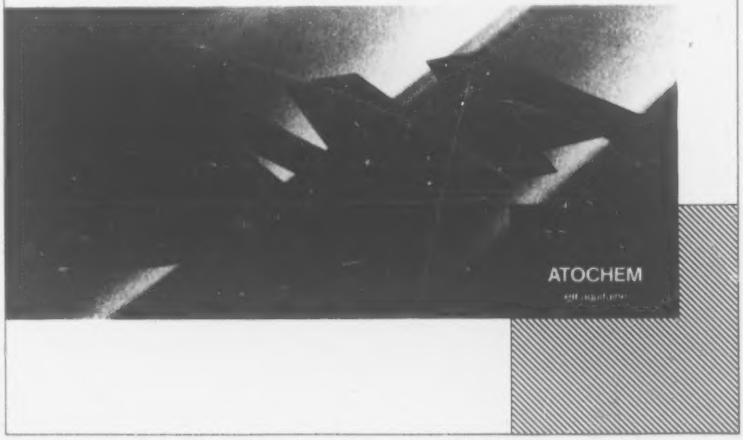

CIRCLE 49 ON READER SERVICE CARD

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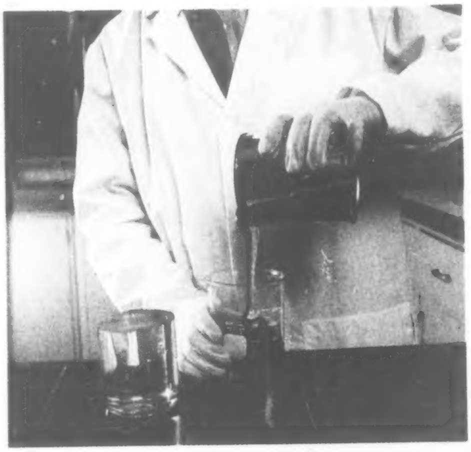

Ciba-Geigy Irgacure 369 acetophenone-class photoinitiator, here being poured into beaker as liquid, can be cured into solid block

a solution. According to Rodney F. Lloyd, manager of market development for the performance chemicals business, the company's Jeffamine polyoxypropylene amines in combination with either aromatic isocyanates, MDI, or TDI, produce a concrete stabilizer that gels in two to three seconds and is tack free in 10 to 15 seconds.

The system can be applied inside manholes and can be used to protect the inside of sewage pipes from hydrogen sulfide breakdown. This polyurea system will not foam on damp surfaces the way polyurethane systems will, notes Lloyd. It provides good mechanical adhesion without pinholes, though Lloyd says it is not the most attractive looking coating. It has an "orange peel" surface because of its rapid cure. "But most users don't care what it looks like," he says, because it is generally used out of sight. Other applications Lloyd suggests for the material is as a seamless lining for man-made ponds where it is applied over a ground stabilizing fabric. Further work is under way to improve adhesion of the material to metal. Lloyd says that Texaco's Austin lab is willing to work with customers to develop applications for the polyurea systems.

Mobay's Cullen believes that the combination of Mobay's isocyanates with Texaco's Jeffamine polyurea chemistry is a potential growth area for both companies. He says many trial applications are under way with the material and thinks it looks most promising for uses on concrete.

Dow Chemical's M. Anthony Johnson, market manager for industrial coatings, says Dow's aromatic isocyanates are used in industrial maintenance coatings when weatherability is not a factor. He estimates that 56% of isocyanates used in industrial maintenance are aromatic isocyanates. Dow is a major supplier of MDI for maintenance coating primers as well as in electrodeposition coatings for automotive uses. He projects growth of the maintenance coatings market at 3% annually.

Dow supplies the maintenance coatings market with liquid epoxy resins, liquid epoxy novalacs, and solvent-blended epoxy resins. These materials may be used as primers, midcoats, and top coats. Where weatherability is a factor, Johnson says that applicators typically use an aliphatic-containing isocyanate coating. To supply the market with a low-VOC resin, Dow has recently introduced DER 362, the company's first low-viscosity, low solvent-containing epoxy resin with good formulations latitude, he says.

According to Glidden's William F. Ashmore, manager of industrial maintenance sales, two-component urethane paint systems make up 40% of the maintenance market. Glidden recently introduced an acrylic-urethane coating system and expects to introduce a lower cost similar coating soon.

Ashmore says that Glidden's Rustmaster Pro is a water-reducible vinyl coating system that gives performance similar to inorganic zinc-epoxy primers followed by urethane top coats. The Rustmaster primer produces a chemical reaction on steel surfaces creating a pyroaurite protective surface. A three-coat system provides low oxygen and moisture permeability. The system has a low VOC content—0.5 lb per gal—and is selling in Florida, with approval pending in Pennsylvania and testing under way in Michigan, says Ashmore. □

OCTOBER 21, 1991

CHEMICAL & ENGINEERING NEWS

Bayer targets prevention as best way to reduce pollution
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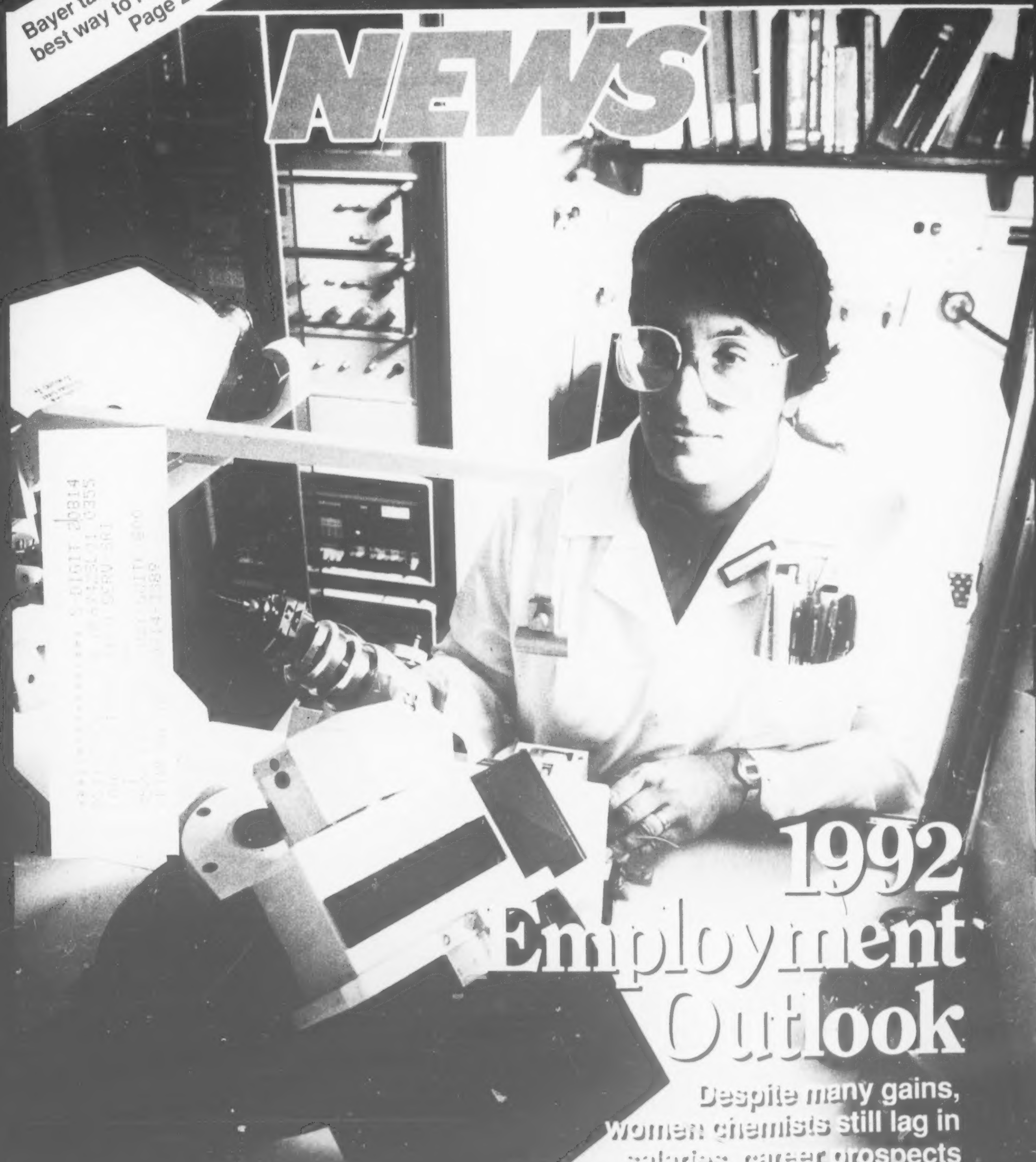

1992 Employment Outlook

Despite many gains, women chemists still lag in salaries, career prospects
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CHEMICAL & ENGINEERING
NEWS

Volume 69, Number 42
CENEAR 69 (42) 1-68
ISSN 0009-2347

OCTOBER 21, 1991

News of the Week

- **Swiss physical chemist Richard Ernst has won the Nobel Prize in Chemistry for his methodological developments in nuclear magnetic resonance spectroscopy.** Page 4
- **Nobel Prize in Physics has been given to French theorist Pierre-Gilles des Gennes for work on behavior of complex chemical systems during the transition from ordered to disordered states.** Page 5
- **Fullerenes include carbon-cage molecules that are much more complex than the perfectly symmetrical prototype, C_{60} (buckminsterfullerene).** Page 5
- **Hubble Space Telescope yields its first true-color photograph of the planet Jupiter.** Page 6
- **Dow Chemical has set up an international panel of outside experts to advise its top officials on environmental, health, and safety issues.** Page 6

Cover: Photo courtesy of NIH

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Business

Concern over environmental, economic problems in Eastern Europe are causing chemical firms to think twice about investing there. **Page 10**

More chemical companies are turning to quality programs to assess, manage, and improve their R&D performance. **Page 11**

Healthy growth lies ahead for water treatment chemicals, according to a recent market study. **Page 12**

Government

Joint research efforts are being explored by a Japanese high-tech agency and three Tennessee institutions. **Page 17**

World Bank claims significant progress in its environmental efforts but so far environmental groups aren't impressed. **Page 19**

Science/Technology

Germany's Bayer targets process modification as way to manage pollution-causing products of chemicals manufacture. **Page 21**

First in-vivo catalysis by catalytic antibody is achieved by reseachers at Scripps Research Institute. **Page 27**

Fluorescent dyes attached directly to DNA probes are ready to market for chromosome "painting." **Page 28**

Awards

ACS award winners: Ibers, Klemperer, Kobata, Kubota, Langer, Lenz, Lieber, May, McCall, and Munson. **Page 49**

Employment Outlook

C&EN's annual look at the job market focuses on women chemists—more are choosing chemistry as a career but few are able to break into the top ranks. **Page 30**

Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

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AMERICAN CHEMICAL SOCIETY
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Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Universal symbol for chemicals

When I read John L. Cox's letter (C&EN, Sept. 9, page 2) concerning a universal symbol for chemicals, I began to wonder what in the world use it could be.

Since absolutely everything in the universe is chemical in nature (except for a perfect vacuum, if such a thing exists), what would you label with this symbol? Would everyone go around with the chemical symbol affixed to their hats, shirts, pants, underwear, socks, shoes, and so on? Would reading glasses have to have separate chemical symbols for each chemical component (such as glass, plastic frames, and metal screws)? Would you be able to see through them if they did?

By how much would the gasoline mileage of an automobile decrease if every chemical component had to carry a label with its appropriate chemical symbol? How would we ever round up the world's flora and fauna so that we could properly label them? How would one go about labeling the separate components of air? Or the dissolved chemicals in natural waters? Would the chemical materials used to make the labels themselves have to bear labels? Where would one stop?

Frank L. Pilar
Professor of Chemistry and Chairman
Department of Chemistry
University of New Hampshire

This is in regard to the letter proposing a universal symbol for chemicals. I was taught in high school that that was an Erlenmeyer flask. Has something changed since the mid-1960s?

George W. Richards
Rochester, N.Y.

Faraday's birthday party

I enjoyed the article on Michael Faraday (C&EN, Sept. 23, page 17) and thought you might like to know what we did to celebrate his birthday. The Michael Faraday Laboratories on the campus of Northern Illinois University house the chemistry and physics departments (thus the naming of Faraday Hall was quite appropriate). This year the university's chemistry and physics labs hosted a birthday bash for Mike complete with cake, ice cream, balloons, speeches, a birthday card, and the like. The event included demonstrations of his work and tours of our facilities.

Local press coverage was good, and we even got our president, provost, and dean of liberal arts and sciences to cut the cake and lead the crowd of about 150 in a rousing chorus of "Happy Birthday." The event was well received. I believe that we must take advantage of every opportunity like this to project chemists as real people, and chemistry as an exciting part of our lives.

Robin D. Rogers
Adviser, Chemistry Club
Associate Professor of Chemistry
Northern Illinois University, DeKalb

It was a pleasure to see the thoughtful story on Michael Faraday. Your readers may be interested to know that, in conjunction with the 200th anniversary of Faraday's birth, the Beckman Center for the History of Chemistry has published a pamphlet titled, "Electrochemistry: a Science at the Interface."

The pamphlet includes "200 Years of Development: an Electrochemical Time Chart" suitable for wall display, and a select bibliography of publications on electrochemical history. We would be pleased to send a free copy of the pamphlet to any interested reader of C&EN.

Arnold Thackray
Director, Beckman Center for the
History of Chemistry
3401 Walnut St.
Philadelphia, Pa. 19104-6228

Oversupply of chemists

David Ostfield's letter (C&EN, Aug. 5, page 2) indicates a feeling that an oversupply of chemists is depressing the job market. I recently advertised locally for an entry-level B.S. chemist's position. I received about 20 responses. I did not receive a single reply from a person with a B.S. degree in chemistry.

Most of the responses came from people with other science degrees, such as microbiology, physics, and the like. I had been a professor of chemistry for 11 years before going to industrial positions. I recall that in the 1970s, armies of students were attempting to get into medical school. What ever happened to those people with science degrees who did not get into medical school? Many of

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velopment cycle, results also were seen.

Over the past eight months, IBM has been trying to apply "market-driven quality practices" to its R&D efforts, says A. Frank Mayadas, plans and controls vice president for IBM's research division. A scorecard system has been created to identify key processes and develop measurement mechanisms in R&D. In ranking R&D achievements of its staff, IBM is trying to include its Nobel Prize winners. He admitted IBM has not yet concluded how it will relate its research processes to market interests.

Most managers seemed to agree that exploratory or innovative research efforts are fuzzier areas and fit less easily into the quality process. Quality programs that look to shorten product development cycle times, reduce costs, and respond to market and investor pressures often are at odds with the longer term outlook of exploratory research.

Ann Thayer

Outlook good for water treatment chemicals

Unit price increases and changes in use patterns are adding greatly to the value of chemicals going to the water treatment market. Although physical volume of water treatment chemicals increased at an average annual rate of about 3.1% per year between 1982 and 1990 to almost 28 billion lb, the market value of those products rose at an average annual rate of 6.7% to $2.4 billion, according to Leading Edge Reports, the Cleveland, Ohio-based market research firm.

According to a recent market study by the firm, continued change and healthy growth are in the cards for the remainder of the 1990s. This growth will come from population growth, regional population shifts, and industrial development. Also spurring growth will be increasing concern about water quality and the resulting environmental legislation, government-mandated water standards, and public funding for water treatment.

These factors will spur 3.3% average annual growth in physical volume of water treatment chemicals to about 39 billion lb by 2000. This would mean a projected value of about $4.3 billion, a more than 6% annual growth rate.

The bulk of the water treatment chemical market, in terms of both physical volume and dollar value, is the category of biological action chemicals. This consists of chlorine, inorganic chlorine compounds, other biocides, oxygen, ozone, and fluorides. But the largest volume of these is oxygen. The Leading Edge study indicates that oxygen alone accounted for about 38% of all water treatment chemicals consumed in 1990.

These biological action chemicals represented the fastest growing major category of chemicals used in the

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Growth will speed up for water treatment chemicals

Millions of lb	1982	1990	2000	% average annual change 1982–90	% average annual change 1990–2000
Coagulants	2,324	2,988	2,985	3.2%	0.0%
Filter media	926	1,335	2,115	4.7	4.7
Neutralizers & salts	10,513	10,114	11,910	−0.5	1.6
Biological action chemicals	8,133	13,472	21,580	6.5	4.8
TOTAL	**21,896**	**27,909**	**38,590**	**3.1%**	**3.3%**

Source: Leading Edge Reports

1982–90 period, with consumption increases averaging 6.5% annually in physical volume and 8.4% per year in dollar value. Rapid growth is expected to continue through the 1990s.

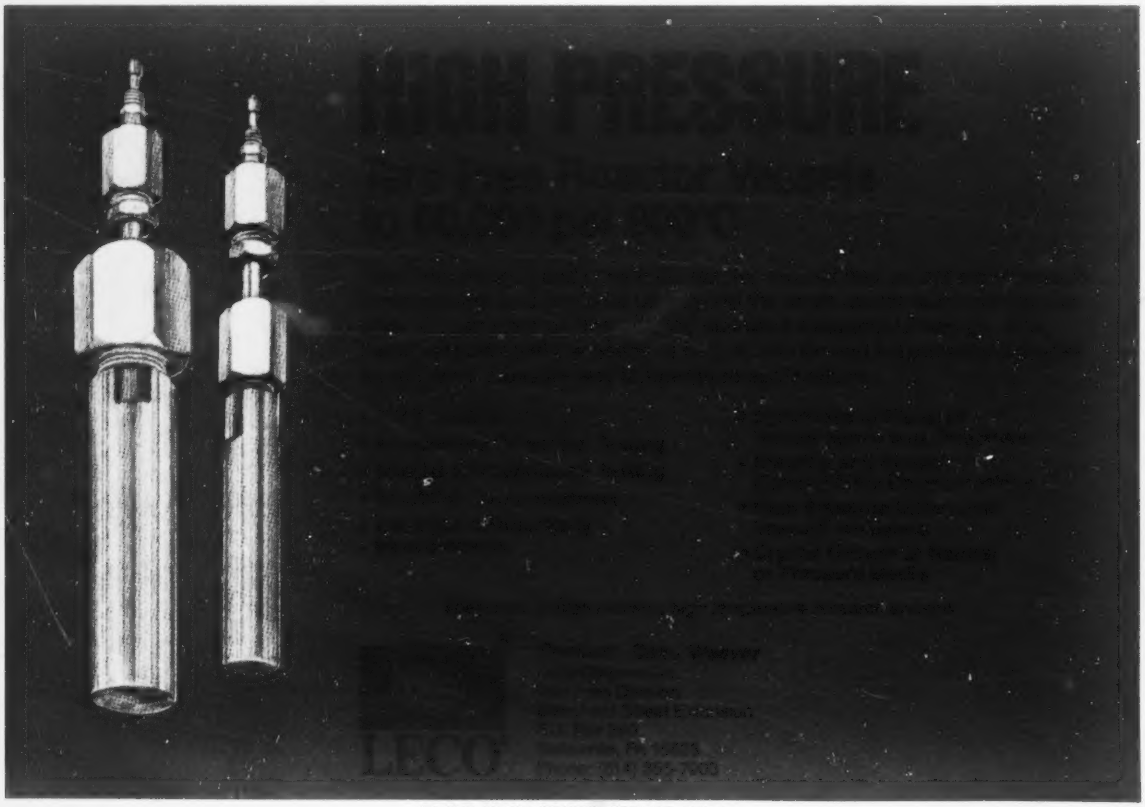
Neutralizers—lime, caustic soda, soda ash, and acids—and salts, are the second largest category with 36% of total volume in 1990, but only 22% of dollar value. The study says neutralizer consumption is being adversely affected by changes in other treatment categories, as well as by shifts in product preference within the category.

Coagulant volume peaked in the mid-1980s and then began to decline, but market value grew 6.8% annually from 1982 through 1990. This growth in market value was attributable to rising use of organic polymer-based coagulants and coagulant aids, which increased in dollar volume at an annualized rate of 13% in a number of treatment applications. All products, except alum, registered strong growth in the 1980s. Alum, however, showed generally flat demand and soft prices throughout the period.

Consumption in the final major market category, filter media—activated carbon, ion exchange resins, diatomite, perlite, and membrane medium—increased 4.7% by weight and 6.4% by dollar value annually during 1982–90. The study finds that, based on market value, this category will represent the fastest growing segment during the remainder of the 1990s, with growth expected to average 7% per year. However, physical volume growth of filter media will only match that of the previous period at 4.7%.

The report, titled "Water treatment chemicals and equipment: Outlook for the 1990s," is available from Leading Edge Reports, 12417 Cedar Rd., Suite 29, Cleveland Heights, Ohio 44106.

William Storck



CIRCLE 23 ON READER SERVICE CARD

1992 Employment Outlook

Bette Hileman and Rebecca L. Rawls, C&EN Washington

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$2SO_3^{2-}$
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Women Chemists

The American Chemical Society's most recent report on the status of its women members finds them making gains toward equity with men in their numbers, pay, and work-related responsibilities. But women remain rare in senior positions in both industry and academe. [illegible]

Demand

Both industrial and academic employers expect hiring to be down for chemical professionals in the upcoming year, as the recession and tighter budgets at state universities take their toll. [illegible]

Salaries

Starting salaries for bachelor's chemists haven't changed much from last year, according to ACS's annual survey. But salaries for chemists with advanced degrees and for chemical engineers at all levels are at least keeping pace with inflation. [illegible]

Career Planning

ACS and other organizations provide help to people planning chemical careers, [illegible] both students and [illegible] time. [illegible]

Growing numbers of women drawn to chemistry careers, but few reach top ranks

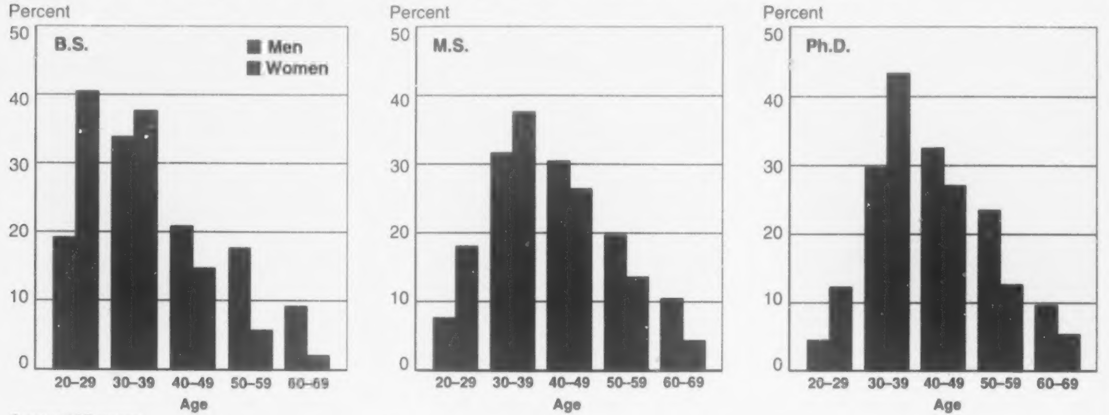
By a number of measures, the profession of chemistry is attractive to women. Since 1970, more than 60,000 women have earned bachelor's degrees in chemistry, receiving some 28% of the total number of these degrees awarded. And the proportion of B.S. degrees going to women increases almost every year, from 18% in 1970 to 39% in 1989, the most recent year for which these statistics are available.

According to a National Science Foundation survey, 35,300 women chemists were employed in 1988, 18% of all employed chemists. In 1978 a similar survey found less than half that many employed women chemists—15,100, or 11% of all employed chemists. By comparison, during that decade, the number of men employed as chemists grew 27%.

In fact, almost every measurable trend shows that women, over time, are making gains toward equity with men in chemistry—gains in their numbers, their pay, and their work responsibilities. Women are moving toward equity, but they still have a long way to go.

Probably the best data available on the current status of women chemists in the U.S. are those col-

Regardless of degree, greater percentage of women chemists are under 40



Source: ACS survey

For women, but not men, salaries stop rising midway through their careers in industry

Years since B.S.	Bachelor's		Master's		Ph.D.	
	Men	Women	Men	Women	Men	Women
0–1	27,330	26,550	—	—	—	—
2–4	29,415	29,000	33,450	$33,000	—	—
5–9	35,000	33,000	36,840	35,820	$47,000	$46,530
10–14	41,500	37,500	43,450	43,000	52,000	50,300
15–19	45,550	41,340	48,800	46,000	59,200	57,793
20–24	50,000	44,916	53,000	48,000	65,250	60,000
25–29	54,600	41,650	56,000	46,150	72,000	60,000
30–34	56,320	44,034	60,000	45,000	73,000	58,200
35–39	57,000	44,330	61,660	51,000	76,000	62,000

Source: ACS survey

lected by the American Chemical Society. Every five years, beginning in 1975, ACS has analyzed its annual survey of the salary and employment of its members in an attempt to evaluate and report on the particular status of women chemists. The most recent of these reports is based on a 1990 survey of all ACS members who live in the U.S., are not older than 70, and are neither students nor retirees. It finds a number of differences between women and men chemists, though the magnitude of the differences is frequently less than it was five, 10, or 15 years ago.

For example, women members tend to be younger. The survey found 40% of bachelor's-level women chemists are less than 30 years old, compared with 19% among bachelor's-level men chemists. More than one fourth (27%) of men but only 8% of women with bachelor's degrees in chemistry are older than 50. The relative youth of women chemists may reflect, at least in part, the increasing proportion of chemistry degrees that have been going to women in the past decade. But if women are more likely than men to become dissatisfied with chemistry as a profession, so that, over time, they leave it in larger numbers, that, too, would contribute to the higher percentage of younger women chemists.

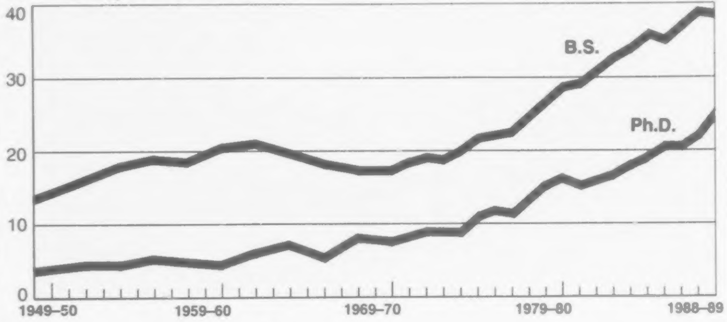
Women are less likely than men to have advanced degrees—39% of the women have doctorates, compared with 63% of men. To some extent, this difference is simply a consequence of so many women in the survey being too young to have yet earned a Ph.D. But at every age level women are less likely than men to have a doctorate. The difference is smallest in the 60 to 69 age group, where 53% of the women and 63% of the men have Ph.D.s.

In 1980, nearly half (49%) of women with doctorates worked for academic institutions, compared with 35% of men with comparable degrees. By 1990, the fraction of women employed at universities and colleges had dropped to 39%, while the fraction of men, at 33%, had stayed essentially constant over the period. A similar shift is taking place in the employment of chemists by federal, state, and local governments. The proportion of women finding employment here has dropped from 17% of all women in 1980 to 14% in 1985 to 10% in 1990. About 9% of men chemists worked for governments in 1990, a level that has remained fairly constant over the decade.

In 1990, 58% of all women chemists worked in industry, essentially the same as the 60% of men who did so. Roughly half the men chemists working in industry have Ph.D.s—50% in the 1980 survey and 54% in 1990. Here, too, the statistics for women are becoming more similar to those of men, with 29% of women in industry having Ph.D.s in 1990, compared with 19% in 1980 and 24%

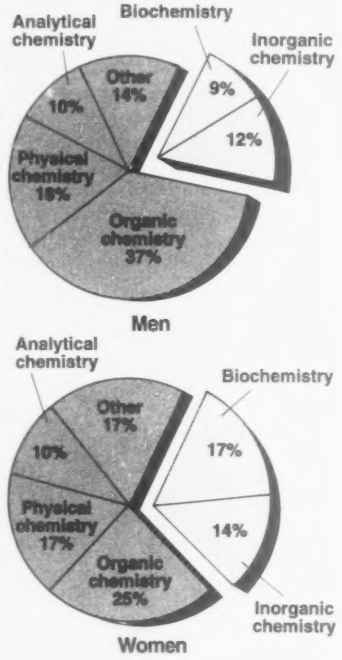
Women's share of new chemistry graduates is growing

Percent of degrees conferred on women



Source: National Center for Education Statistics

More women than men in inorganic, biochemistry



Source: ACS survey

in 1985. However, women chemists in industry are much younger than their male counterparts—30% of them are in their 20s, compared with 9% of men. Similarly, only 27% of women in industry are 40 or older, compared with 56% of men.

Women are more likely than men to work for companies outside of manufacturing or for firms that make pharmaceuticals, biochemical products, and soaps. They are less likely than men to work for the relatively higher paying companies that manufacture plastics, specialty chemicals, or rubber. And they are much less likely to be managers. For both men and women chemists, the most likely type of work is applied research—38% of each sex indicate this is their primary work function. For men, the second most likely task is R&D management, which is the primary work of 18% of them. Only 7% of women are R&D managers—much more common functions are production work (14%) and basic research (13%).

About 20% of women chemists in nonacademic jobs accept positions where they see little possibility for professional advancement. This fraction has held constant through the 1980, 1985, and 1990 surveys. The surveys indicate, however, that the number of men who take such jobs is rising. In 1980, 15% of men in their first year on the job felt they had little chance to advance professionally, in 1985 19% thought so, and in 1990 23% held that view.

Once on the job, women's perceptions of their opportunities are improving. At any time, younger women are more likely to see chances for advancement than older women. And once they get five or more years beyond the bachelor's degree, more women at every stage in their careers were optimistic about their prospects in 1990 than had been the case in 1980. In addition, since 1980, the fraction of women 35 to 39 years beyond their bachelor's degrees who see little chance for their own advancement has been going down—from 46% in 1980 to 37% in 1990.

In 1990, nonacademic women saw their chances to become managers as much the same as their chances for professional advancement—about 20% of those within a year of their bachelor's degrees felt they had little chance to become managers, and this fraction rose with age to 39% of those 35 to 39 years beyond their bachelor's degrees. These numbers are down substantially from the 1980 survey, when 30% of women in the first year past their bachelor's degrees thought they had little chance to become managers, more than half of all women 20 or more years past the bachelor's degree thought so, and two thirds of women 35 to 39 years beyond the bachelor's degree held this view. There is no clear pattern for men.

Although their expectations seem to be changing, women don't seem to be actually making much headway in moving into R&D management positions. In 1980, 7% of women chemists in industry were R&D managers, the same percentage as in 1990. Twenty percent of men chemists in 1980 were R&D managers, compared with 18% a decade later. Relatively few chemists of either sex are general managers. For both men and women, this fraction dropped very slightly from 1980 to 1990, so that in 1990, 4% of women were general managers, compared with 5% in 1980. For men, the change was from 8% to 7%.

In 1990, the salaries of women chemists just beginning their careers in industry were generally the same as men chemists. As they get older, however, women's salaries climb more slowly than those for men. Even when adjusted for age, experience, degree, type of employer, or work function, older women chemists earn less in industry than men do. For instance, women with Ph.D.s working in the pharmaceutical industry 20 to 24 years after receiving their bachelor's degree earn 92% of what men in the same position do. And although women Ph.D. analytical chemists who are 15 to 19 years beyond their bachelor's degree earn 97% of the salary of comparable men, the gap widens to 91% for the same work specialty at 20 to 24 years beyond the bachelor's degree. For analytical chemists whose highest degree is a bachelor's, women 15 to 19 years beyond their degree earn 9% less than comparable men; with 20 to 24 years experience, they earn 11% less.

Among academic chemists, too, women have been making some gains relative to men, but the gains are most apparent on the lower rungs of the professional ladder. Important points of comparison for academic chemists are tenure, rank, and salary. By and large, ACS members employed at colleges and universities, whether men or women, have doctorates. Tenure remains more common for men than for women. In 1990, half of women Ph.D. chemists at academic institutions were either tenured or on a tenure track, compared with 75% of men. Of those with the rank of assistant, associate, or full professor, 58% of the women chemists and 80% of the men had tenure.

In the 1985 survey, women chemists held 3% of the full professorships at Ph.D.-granting institutions; in 1990, they held 4%. Altogether, 62% of the men and 55% of women chemists working in higher education in 1990 were working at Ph.D.-granting institutions, compared with 60% of the men and 48% of the women a decade earlier. Women are much more likely than men at these institutions to be instructors or in nonfaculty positions, and it's unclear whether they are gaining or losing ground in this area. In 1980, 30% of women and 8% of men held such positions; in 1985 these fractions had risen for both men and women to 50% and 16%, respectively. In the 1990 survey, women had dropped back to 39%, while the fraction of men serving as instructors or in nonfaculty jobs remained at 16%.

The way men and women faculty members spend their job time is becoming more similar. In 1985 nearly half (46%) of women faculty spent at least three fourths of their time teaching, compared with one third of men chemistry faculty who did. About 10% of women and 8% of men spent at least three quarters of their time on administration, and 5% of women and 3% of men were full-time researchers. Last year, 37% of women chemists and 30% of men spent three quarters or more of their time teaching, 6% of both sexes spent at least three quarters of their time on administration, and 17% of women and 11% of men spent all of their time doing research.

As in industry, the ratio of women's to men's salaries in academia has increased overall since 1980, but as faculty get older, the gap between women's and men's salaries widens. For full professors, women in 1990 earned 90% of what men did, even among older faculty. A decade earlier, women professors earned between 80 and 90% of what their male colleagues earned, depending on their age. At the associate professor level in 1990, women's salaries relative to men's move downward with age from being equal with men's 10 to 14 years beyond the bachelor's degree to being only 80% of men's for those 35 to 39 years beyond the bachelor's degree. In 1980, the transition was more abrupt, with women dropping from making salaries that were 97% those of men 20 to 24 years beyond the bachelors to 80% of men's 25 to 29 years beyond that degree.

Starting salaries of women assistant professors are not keeping pace with those for men. In 1980, women started at 103% of men's salaries; by 1985, they were starting at 97% of men's salaries; and in 1990, their starting salaries had dropped to 94% of men's. This gap comes about not because women's salaries are declining, relative to men's, at comparable institutions, but because more and more women assistant professors are working at schools whose highest degree offered is the master's or bachelor's. Such schools typically pay their assistant professors less

Women chemists tell of frustration, inequality in workplace

If numbers show that, over time, both the status of women chemists and the women's perceptions of their opportunities are improving, the comments of women who participated in ACS's 1990 survey paint a different picture. ACS's latest survey report includes extensive, anonymous quotes from respondents. The picture they paint is one of anger, frustration, and inequality. "Don't read through the comments all at one sitting," advises Kathleen D. Trahanovsky, who chairs the ACS Council Committee on Women Chemists. "That's very depressing." Here are samples:

"I want to believe I have an equal opportunity; however, it is very difficult. I feel I must work 100% harder than my male counterparts for half the credit. I have an example where I saved the company thousands of dollars solving an existing problem and, although I was recognized companywide in an announcement, I did not receive a bonus, just a company sweater. I know in the past male employees contributing this way received financial reward."

"Chemistry remains a profession dominated by males and the male ego. Even in the best of companies, women Ph.D.s are treated as semisecond class citizens among Ph.D.s in terms of responsibility assignments, supervisory assignments, and subordinate assignments. In graduate school, women always had to work much harder and much more to be awarded their degrees; in industry, it is even more so. It seems the intelligence of women Ph.D.s has no weight against the occasional luck of their male counterparts. Is it frustrating? You bet it is."

"Professors still pride themselves on discouraging people from pursuing scientific careers, especially women. My graduate institution has had a large number of gifted women chemists leave school because of this. My year alone, seven women were in inorganic chemistry, only one is left. The others left school or sought degrees in other areas of chemistry that were less discriminatory (that includes me)."

"Although I have observed attempts on the part of industry to treat women chemists more fairly, this appears to be true only for the younger and less experienced ones. Those of my generation, with more years of experience, still suffer from subtle discrimination and no attempts seem to be forthcoming to right previous wrongs."

"The structural discrimination in academics is amazing. It's not attitudes that are so much a problem anymore, since

those have changed a lot over the past two decades. It's institutional rigidity and unintended social messages that hurt. In 20 years I have heard over 2000 departmental seminars in chemistry by visiting lecturers. Two have been by women. I have never had a female instructor in chemistry. My university hired its first woman, in over 100 years, two years ago. These messages do matter."

"Sexual harassment is still a very serious problem in the industrial chemical workplace. Women do not have confidence in their employers to handle the problem and often remain quiet in fear of losing their jobs. There is a definite glass ceiling in most companies for women on both managerial and technical ladders. The career ceiling is often not very much higher than entry level."

"Currently I report to a female director. She earned the position in January 1990. It is the first time my employer has appointed a female director for R&D. My salary lagged behind my male contemporaries until 1980 when I received two promotions and a 30% increase in pay in one year. Recently new employees are starting out at the same pay rate, and sex discrimination at the start has been eliminated. Change is slow, but the changes are positive. I see a positive future for female chemists in industry and I hope I'm around long enough to see what the future holds."

"[There is] a very real problem women face in trying to compete in mainstream academic research. Such a setting is not geared to those of us constrained to make breakfasts and dinners, to put kids to bed, and to be in town, at home, when our kids are growing up (usually during peak tenure-making years). Does that mean women can't contribute to science through academic research? Of course not, in theory, but in practice, yes!"

"I am employed by an international company which has an equal employment opportunity policy. I expect to rise one level. Beyond that, all of the higher echelon is male. I anticipate that this will be the case for many years. I will probably have to become self-employed to pursue higher ambitions. It's called the glass ceiling, you don't see it, but it's there."

"I believe that women in chemistry have not fared well. High positions continue to be dominated by males. It is a boy's world and there seems to be no relief in sight. In my company, there has never been a woman in senior management, even though 50% of the employees are women."

than do Ph.D.-granting schools. In 1985, 30% of women assistant professors worked at B.S.-granting institutions and 28% at M.S.-granting ones. By 1990, these fractions had risen to 43% and 31%, respectively.

In all types of employment, the survey found several common themes: Although salaries have improved for women relative to men since the 1980 and 1985 surveys, salaries for older women continue to be substantially below those of older men, women report a "glass ceiling" that impedes their progress in both professional and managerial advancement, and women express concerns about how to relate careers in chemistry to family concerns, such as the demands of two-career families and child care.

To gain more information as to why women are not moving into the higher ranks of the chemical profession at the same rate that men are, ACS is in the process of collecting data from an age-matched sample of women and men ACS members. This survey, expected to be completed in the first half of next year, will look for connections between career advancement and the perception of discrimination in the workplace as well as the demands of family responsibilities.

The new ACS survey closely resembles one conducted by the Royal Society of Chemistry in 1988. That survey of some 2600 British chemists found different career progression and promotion opportunities for men and women. Half of the women and 65% of the men said they had not encountered sex discrimination at work. For those who had encountered it, the discrimination was much more frequently perceived to be against women.

Nearly one third (30%) of the men and 17% of the women in the British survey thought men had an advantage in obtaining jobs, compared with 1% of men and 8% of women who thought women had the advantage. In the case of promotion, just over one fourth of both men and women thought men more likely to be promoted than women, compared with 2 to 3% who thought women had an advantage here. This perception of a disadvantage in promotion for women was highest (35%) among mid-career women.

Most men (81%) and women (61%) said they had not encountered sexual harassment on the job, but one fourth of the women and 16% of the men said they had encountered it against women (other than themselves). One fourth of the women said they had themselves been sexually harassed at work.

The stresses of dual-career families and of child rearing seem to fall more heavily on women than men in the British survey. Of people living with spouses or partners, more than 90% of both men and women said their partners were supportive of their careers. However, 88% of the men, compared with 47% of the women, said their partner would be willing to relocate to fit in with their careers. Two fifths of the men and half of the women said their careers had been affected by their partner's unwillingness to relocate.

One woman in six in the survey had taken a break in her career. Most often these breaks began when the women were between age 26 and 30, lasted three years or more, and were to take care of children. Child care facilities available at work were not considered adequate to meet the need for them. On returning to work, 44% of the women thought that their job responsibility had deterioriated while they were gone. Only 3% of the men had taken career breaks, and these were usually for less than four months and were for reasons other than taking care of children.

A more detailed presentation and analysis of the survey findings is available in "Women Chemists 1990," which can be purchased for $39.95 from the ACS Distribution Office, Room 210, 1155—16th St., N.W., Washington, D.C. 20036. □

Demand

With several key chemical companies and universities in the midst of cost-reduction programs, recruiting will be down this fall

Demand for chemists and chemical engineers will be down substantially in 1992. Signs of softening were already apparent by the end of September, when this year's recruiting season unofficially began, and most recruiters, college placement centers, and student advisers contacted by C&EN expect the number of entry-level jobs available to shrink a good deal further in the coming year.

The reasons are almost entirely economic. "The U.S. economy overall has been in a recession for a year," explains James D. Burke, manager of professional recruiting for Rohm & Haas. "Prior to that, we had eight years without a recession. Companies have overextended their research staffs. Now they will need to be very conservative about hiring" to get through these leaner economic times, Burke predicts. "Nobody wants to have layoffs," he adds.

Yet some positions for chemical professionals already have been terminated and, almost certainly, the coming year will bring more. Many major chemical producers—among them Monsanto, Du Pont, Union Carbide, Allied-Signal, Arco Chemical, Hercules, Occidental Petroleum, and Phillips Petroleum—have announced (or in some cases completed) major cost reduction programs that include significant reductions in staff size.

Most of the staff cuts will not be from the ranks of chemists and chemical engineers, and by far the largest part of these cuts will be made by not replacing people who choose to leave, either through ordinary retirement or to take advantage of special incentives to do so that companies will be offering. However, several companies have already announced that before it's over, they expect to be terminating some workers. Thus, even the demand for presently employed chemical professionals may decline in the coming year.

Nor is the picture bright for those seeking academic employment. Although an aging faculty makes vacancies produced by retirement more and more common in university chemistry departments, serious budget constraints, particularly at state universities, limit the number of those vacancies that can be filled. And the escalating costs associated with setting up a new assistant professor at a research university are adding to the difficulty of hiring new faculty.

Altogether, 1992 may be the worst year in nearly a decade to be seeking work as a chemical professional. Still, there is recruitment going on, and particularly well-qualified candidates will continue to have their choice of offers in both industry and academe.

At the bachelor's level, the combination of steadily declining class sizes and a rising share of chemistry graduates going on to graduate or professional schools means there are many fewer new graduates looking for jobs than there were in the last recession, which occurred in the ear-

Chemistry bachelor's degrees have declined 26% in past decade, while chemistry Ph.D.s have risen 34%

	Degrees awarded in chemistry			Degrees awarded in chemical engineering		
Academic year	**Bachelor's**	**Master's**	**Ph.D.**	**Bachelor's**	**Master's**	**Ph.D.**
1978–79	11,643	1765	1518	5655	1149	304
1979–80	11,446	1733	1551	6383	1271	284
1980–81	11,347	1654	1622	6527	1267	300
1981–82	11,062	1751	1722	6740	1285	311
1982–83	10,746	1604	1746	7145	1304	319
1983–84	10,704	1667	1744	7475	1514	330
1984–85	10,482	1719	1789	7146	1544	418
1985–86	10,116	1754	1908	5877	1361	446
1986–87	9,661	1738	1976	4983	1184	497
1987–88	9,052	1708	1995	3917	1088	579
1988–89	8,654	1785	2034	3684	1097	599

Source: National Center for Education Statistics ly 1980s. At midsummer, unemployment among recent bachelor's-level chemistry graduates (those in their first year after graduation) was above 14%, according to ACS's annual starting salary survey, up from 13% the summer before and 10% in the summer of 1989. Unemployment for new bachelor's chemists went as high as 18% in 1983, according to the survey.

These same demographic factors are working against new chemistry Ph.D.s. Graduating classes are a third larger now than they were a decade ago. And unemployment among new Ph.D. chemists, which stayed below 4% throughout the recession of the early 1980s, has risen sharply in recent years. This summer found it over 11%, according to the ACS survey, up from 10% a year earlier.

The picture is more rosy for new chemical engineers. Although the forces that are reducing demand for chemists affect chemical engineers as well, the effects likely will be more moderate. Chemical engineering graduates have been in very short supply and more highly sought after than chemists for the past several years. Compared with chemists, chemical engineers more often are employed in the petroleum industry, which, though feeling the effects of the recession, has not been so hard hit as the chemical industry.

With a major cost reduction program already announced, Du Pont will be recruiting about one fourth the number of professionals it usually does, says Kevin McCormack, manager of professional staffing. This reduction will apply to both chemists and chemical engineers. Many of the positions will be filled by people who already have a relationship with the firm—through cooperative education programs, summer internships, or company-sponsored scholarships. Because there are so few openings, Du Pont will not be recruiting on campuses.

"Historically, we bring in a certain number of new graduates each year to refresh the pipeline and keep our staff well balanced with new ideas," McCormack says. "We won't be engaging in as much of that this year."

In July, Du Pont announced a $1 billion companywide program to reduce fixed costs in virtually all areas outside of manufacturing. The program will last for one or two years and is intended to make the company more competitive. Most of the areas where chemists and engineers work, including fibers, engineering, central research, medical products, and safety, health, and environmental affairs, have announced their restructuring plans in recent weeks.

Although not intended primarily as a personnel reduction program, McCormack says, "there will be people leaving the company, voluntarily, as much as possible." Some employees are being offered incentives in the form of enhanced pensions, lump-sum payments, and seminars in career and financial planning. In addition, people are being redeployed within the company. Most of Du Pont's needs for chemists and chemical engineers in the coming year will be filled by these internal transfers, which already have begun. This includes many of the hiring needs of Du Pont's petroleum operations, which heretofore have recruited separately.

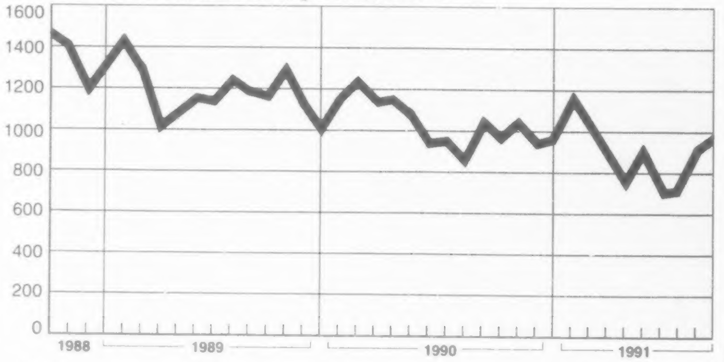
Union Carbide, too, is in the midst of a cost reduction program, which aims to cut costs by $250 million a year by 1994 and to reduce the work force by 5500. Most of these staff reductions—about 3700—already have taken place and probably do not heavily affect the company's chemists and chemical engineers, although they do include some, says Thomas J. Neelen, manager of professional placement.

For chemical professionals, probably the biggest impact is on recruitment, which will be down substantially this year. Carbide will be doing on-campus recruiting this fall and next spring, but, especially at the bachelor's level, the number of positions available will be small. The company will be hiring Ph.D. chemists very selectively, at about half the level of recent years, Neelen says. Hiring will be only a third of usual numbers for bachelor's- and master's-level chemists and chemical engineers, and an increasing fraction of these new-hire positions will be filled by students who have previously worked at Carbide either in co-op education programs or as summer interns.

The company would be shifting to this source of bachelor's-level candidates even if overall needs were not down, Neelen says. Getting to know students fairly well through several months of employment makes for a much better match than can be done through interviewing alone. Not only is Carbide more satisfied with new employees that it gets by this route, but the retention rate also is much higher, indicating the students, too, have had a better chance to evaluate what kind of work they are being hired for and to decide whether it's what they're looking for. Carbide plans to be hiring half of its bachelor's-level candidates from this source within the next few years, Neelen says. Co-op and summer employment oppor-

Help-wanted ads in C&EN continue three-year decline

Volume of "positions open" advertising,[a] column-inches



[a] Column-inches published during consecutive periods of four weeks each; no issues were published in the last week of 1988, 1989, and 1990.

tunities for students have not been cut back this year, he adds.

Even in lean times, "any organization needs to be bringing in new employees," Neelen says. Thus, although the number of job openings is down this year, "it's still critical for the future to be bringing in new chemists and chemical engineers. We do have ongoing annual commitments to do this, regardless of the current economic climate."

Monsanto is in some ways one step ahead of some of the other major chemical producers, in that its restructuring began in late 1990 and is now essentially complete. Three key areas of the company where chemists and chemical engineers work have all had fully subscribed voluntary programs to reduce staff—agriculture, chemicals, and corporate research, explains Robert J. Mason, corporate director of university relations. Now, Mason says, "life has gotten better. Signs indicate the recession has eased off some," and the company plans a full schedule of campus recruiting this year. The need for chemists and chemical engineers will be "basically normal," he predicts, although, as is always the case, hiring plans will be revised early in 1992.

In part, this year's demand is a carryover from last year, when recruitment targets were low, as a result of restructuring. In some areas, last year's incentives to encourage employees to leave were too effective, so some of Monsanto's recruiting this year is to fill vacancies caused by these departures.

Dow Chemical isn't restructuring, but its recruitment will be down this year. The company expects to hire about a third as many chemists and chemical engineers at all degree levels as it usually does, says Smallwood Holloman, manager of mid-East recruiting and college relations. The firm will be making trips to campuses, looking particularly for bachelor's-level candidates, and, as has been the case in recent years, looking hardest for chemical engineers. "We keep getting signals that the recession is over, but we haven't seen a turnaround yet," Holloman says.

Rohm & Haas, like Monsanto, isn't predicting major reductions in its demand for chemical professionals this year. The company will be hiring somewhat fewer Ph.D. chemists than they intended to hire last year, says Rohm & Haas' Burke. Last year the company hired more doctoral chemists than it started out to "because the pool was so good," he adds. As other companies cut back on their Ph.D. hiring last year, Rohm & Haas found itself with a bigger selection of high-quality candidates. Most of this year's reduction is to offset last year's greater hiring. At the bachelor's and master's level, hiring will probably be up modestly this year, principally to provide more support staff for the recently hired Ph.D.s.

Similarly, PPG Industries' manager of professional employment, Joseph Schewe, is cautiously predicting that that company's needs for chemists and chemical engineers will be down only slightly this year. Although budgets are not all in yet, the company is not restructuring and hopes to be hiring to add people to its professional work force. "I don't want to sound too optimistic," Schewe adds. "If the recession keeps on, things could look bad in a couple of months."

Petroleum firms such as Exxon are still recruiting aggressively for chemists and chemical engineers. Hiring targets in both fields have been scaled back about a third at Exxon, but the company's recruiting schedule hasn't been reduced. And particularly for chemical engineers, the company still expects demand to be very high.

At universities, an increasing number of chemistry faculty are reaching retirement age each year, which should mean a healthy demand for new Ph.D. chemists to fill tenure-track positions. But it isn't working out that way, says Paul G. Gassman, professor of chemistry at the University of Minnesota. Particularly at state universities, many of which have been hit by major budget cuts this year, chemistry and other science departments are finding themselves with more vacancies than they have funding to fill. The biggest stumbling block, Gassman says, is the cost to set up a laboratory for a new assistant professor. Setup costs are now in the range of $200,000, an order of magnitude higher than they were 10 years ago.

The departments find themselves in a particularly vicious cycle, Gassman says. Qualified candidates for academic positions are very hard to find, despite the need, he says. And when positions go unfilled for too long, the university is apt to take them away. He cites the example of his own department, which tried unsuccessfully to fill three vacancies last year. Three more faculty have now retired, leaving the department short six positions. However, the university has only authorized hiring for two positions this year.

Minnesota is not alone. The Council for Chemical Research is in the midst of a survey of, among other things, faculty vacancies in chemistry departments at member universities. The 74 departments that have responded so far report they are seeking to fill 103 faculty positions. More than one third of the positions have been vacant for at least a year.

How long will the depressed hiring last? Class size is building up at universities, and so is the pressure to fill the vacancies that haven't already been lost, even if doing so means accepting somewhat lower quality applicants. Quality standards have gotten very high during the recent period of relatively few vacancies and increasing numbers of Ph.D. graduates, and some department chairmen privately acknowledge that these standards may have to come down before current vacancies can be filled. But for now, many departments seem to prefer to increase class size, defer sabbaticals, and keep looking for the kind of junior faculty they want, even if they risk losing the ability to fill their vacancies by doing so.

As for industry, recruiting won't go up until the economy does, and for chemicals, that hasn't happened yet. As is usually the case, many companies will revise their recruitment goals for this academic year sometime in early 1992, after they have their own year-end performance data. But few recruiters are predicting those revisions will go upward. And what the picture will be like a year from now is impossible to tell. "For one or two years it may be bad," is the way Du Pont's McCormack puts it, "but we're not going away." □

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CHEMICAL & ENGINEERING
NEWS

Soda Ash

Demand and prices resist recession
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Volume 69, Number 43
CENEAR 69 (43) 1–48
ISSN 0009-2347

CHEMICAL & ENGINEERING
NEWS
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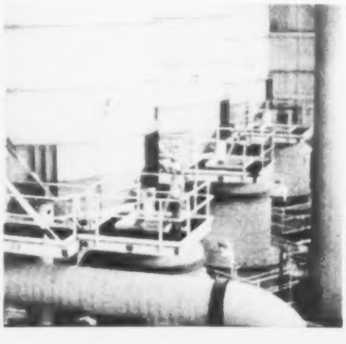

Cover Story

Demand for soda ash will be down slightly this year as a result of recession, but is forecast to bounce back in 1992, thanks in large part to increasing export business. Page 9

Chemical & Engineering News
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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-4432
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Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

Promoting science

Much has been written recently on the need to promote science to high school students and on the usefulness of the ACS SEED program pertaining to minorities. However, readers may believe that the SEED program is applicable only to universities and colleges.

It is true that virtually all of the students are hosted by universities and colleges, but that does not mean that industry cannot participate also. On the contrary, industry can benefit greatly while helping worthy students.

We at Unilever Research U.S. enjoyed the company and help of two excellent SEED students this summer. The students learned a lot and we profited from their hands-on help in the laboratory. Obviously, the work they carried out cannot be discussed openly like university research, but they can talk about techniques they have learned and a general description of the work carried out.

I would urge my colleagues in industry to participate in the program. The pleasure on the faces of the students is reward enough.

Allan H. Gilbert
Special Assistant to the President
Unilever, Edgewater, N.J.

Adversary relationship

The disagreement between D. Allan Bromley and Office of Management & Budget (OMB) director Richard G. Darman (C&EN, Sept. 16, page 4) is an ideological one, reflecting the White House's long-time adversary position vis-à-vis business, which has characterized many administrations. To this has been added the Bush Administration's free-market and budget-busting attitudes.

My own experience as an adviser in the Kennedy round of trade negotiations (as chairman of the Synthetic Organic Chemical Manufacturers Association's International Commercial Relations Committee) revealed the adversary relationship that existed then. Whereas we were held at arms length, major British and German chemical manufacturers literally told their negotiators what positions to take.

Currently, OMB attempted to reduce physicians' reimbursement by $7 billion, contrary to the legislative history of the Relative Value Scale enacted by Congress. Since this was a breach of faith, 90,000 to 100,000 angry letters from physicians caused Congress to hold fast and not agree with OMB.

It is hoped, in the interest of focusing public attention on critical technologies, that scientists and engineers will mount a similar campaign for the planned institute's appropriation. The paltry $5 million requested is peanuts compared to the savings and loan scandals. It is important for government and industry to work together effectively. I hope your readers will respond. Global competition requires that our government assist in reducing to practice the fundamental discoveries we are now developing before our trading partners take advantage of them.

Ernest M. May
Summit, N.J.

Organic compounds in glass

In light of the recent "discovery" of the lubricating properties of boric oxide and subsequent debunking by A. J. Byer, (C&EN, July 22, page 3), it seems appropriate to comment on the report of the "inclusion of organic compounds in glass for the first time" written in the cover story (C&EN, May 27, page 24).

In fact, the inclusion of complex organic molecules in solid glass was described at least as early as 1948 (Kasha, M., *J. Opt. Soc. Am.*, **38,** 1068) and has been described in a variety of glasses, including hydroborates and hydrosilicates, zinc and alkali phosphates, and tin fluorides, to name a few. The concept was patented for solid glasses in 1983 (Paul A. Tick, U.S. Patent no. 4,379,070) and the concepts of fluorescence and phosphorescence, photochemistry and optical nonlinearity demonstrated [Tick, Paul A. et al., *J. Opt. Soc. Am.*, **4,** 1030 (1987)].

The inclusion of organic compounds in porous glasses, which is considerably easier to accomplish, was described in the 1960s. Xerogels are one member of a group of inorganic porous glasses and are not unique in the realm of porous glasses [Brinker, C. Jeffrey, Scherer,

Continued on page 47

Correction

- Oct. 21, page 23: The units for wastewater pollutants shown in the table are lb per day, not millions of lb.

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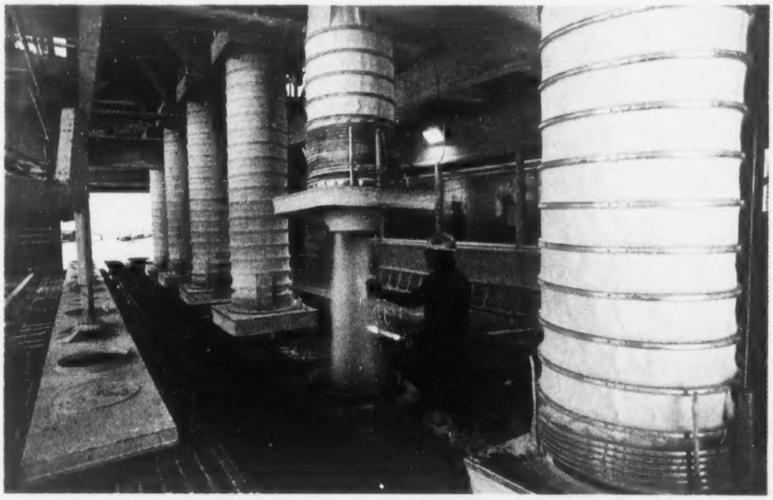
Demand for Soda Ash Holding Up Well During Recession

Consumption of commodity will slip only slightly this year and is expected to rebound in 1992, aided largely by strong growth in exports

Bruce F. Greek, C&EN Houston



Worker samples soda ash as railcar is loaded at Tenneco's Green River plant

Making and selling soda ash has become one of the most recession-resistant segments of the chemical industry. Plants currently are being operated near optimum capacity, and demand, which is expected to be down only slightly from last year, is forecast to rebound in 1992, aided by export growth. What's more, prices are holding up, although they're discounted as usual. And capacity is continuing to be expanded.

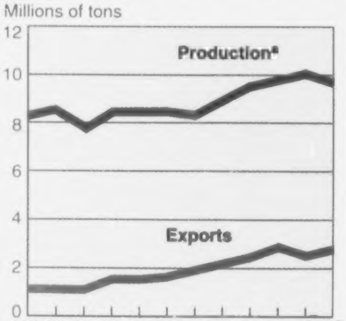
Nevertheless, soda ash remains far from the rapid-growth commodity that typifies many organic chemicals, such as some plastics. Globally, the two dominant soda ash markets—glass and chemicals—either meet strong competition from other materials or meet environmental and economic constraints, which tend to reduce use. However, environmental factors are strongly aiding growth of some smaller uses of soda ash, such as flue-gas treating and processing in the pulp and paper industry.

Despite competition from other materials and the efforts to reduce consumption in major uses such as glass containers, soda ash demand in the U.S., including exports, will continue to grow. According to Roger E. Shamel, president of Consulting Resources in Lexington, Mass., soda ash use will grow on average close to 3% per year through 1995. Production of soda ash, closely tied to demand, likely will fall to about 9.9 million tons this year from the record output of 10.1 million tons in 1990. Next year's expected recovery in demand, which may already be under way, likely will easily put soda ash back on its growth curve for the first half of the decade.

Global demand for soda ash also will keep growing, says Richard J. Regan, vice president of soda ash marketing for General Chemical, Parsippany, N.J. He estimates that long-term growth will average 1.5 to 2% annually, from a 1991 global demand of 32.5 million tons. More than two thirds of this demand will be supplied by synthetic soda ash manufactured outside the U.S. This year about 500,000 tons of natural soda ash will be produced from sources outside the U.S.

In the near term synthetic soda ash poses strong competition with U.S. exports of natural soda ash, according to several industry sources. Removal of the large antidumping duty ($67 per ton) in 1990 against

Soda ash output sags as exports move up this year



a Synthetic and natural soda ash combined prior to 1987. b Estimate. **Sources:** Bureau of Mines, Department of Commerce

U.S. soda ash going to Western Europe will continue to help export shipments near term. Longer term, energy and environmental costs of making synthetic soda ash in areas such as Eastern Europe could lead to the closure of old plants using the synthetic, or Solvay, process based on salt and limestone. Reduced output of synthetic soda ash for regional sales could further open new markets to U.S.-supplied natural soda ash.

U.S. demand for soda ash has slipped this year because of recession-related declines in glass sales, especially flat glass, which is used in automobiles and commercial buildings. Exports, however, continued to grow this year and are expected to total about 2.8 million tons, or 29% of the 1991 production.

Although demand for soda ash will decline slightly in 1991, plants will be operated at an average of more than 90% of their design capacity this year. Inventories of soda ash normally are low because of the high cost of storage relative to a list price of $98 per ton. Much of the inventory exists as material in railcars in transit. As a result, demand, rather than inventory building and reduction, causes the major changes in the level of plant operation.

Rising demand for soda ash will be met by a continual series of capacity expansions, says Shamel. By 1995, when demand could reach 12 million tons per year, announced additions will add 1.4 million tons to total annual capacity. Unannounced plant debottlenecking easily could add the remainder of capacity needed to meet demand during the next five years.

While total demand for soda ash is increasing slowly, its pattern is undergoing more rampant change. Notable changes over the past two decades have been in the shares of consumption by the two largest segments of U.S. demand—glass and exports. Glass has lost share of consumption, and exports have gained.

In 1980, glass containers in the U.S. accounted for about 40% of demand for soda ash, says William L. Breunig, venture director for FMC's alkali division. In 1990, containers probably required only about 20% of U.S. soda ash demand.

Three major developments have affected demand for soda ash in making glass containers, says Richard L. Hogan, vice president of marketing for Tenneco Minerals. The most significant has been the replacement of glass containers by plastics. The greatest impact was the commercialization of the 2-L soft-drink bottle, although the shift to plastic bottles for various foods and alcoholic beverages also has reduced use of soda ash. Although major shifts from glass containers may be complete, minor replacement by plastics likely will continue.

Another development has been the rapid growth of recycled glass,

Resurgence of the lime-soda process

Manufacture of caustic soda (sodium hydroxide) without the coproduct chlorine has been surging, reviving the nearly two-centuries-old lime-soda process. Rising caustic soda selling prices and the continuing high cost of electrolytic caustic soda are prompting producers to seek a lower cost way to meet increasing demands for caustic.

Renewed use of the lime-soda process is being spurred indirectly by environmental concerns about the byproducts from use of chlorine as a bleaching agent in pulp and paper manufacture and about the use of various chlorine compounds as solvents and chemical intermediates. Chlorine demand in these and other uses is expected to decline during this decade. Following recently lowered demand, chlorine prices have declined, causing an increased share of the cost for electrolysis of brine to fall on caustic.

Recent sporadic use of the lime-soda process in the U.S. began in 1988, when chlorine demand had weakened so much that caustic soda prices had to be increased steeply to cover more of the costs of making an electrochemical unit (roughly 1.1 lb of caustic soda and 1 lb chlorine) by electrolysis of sodium chloride brine. The recession also lowered chlorine demand and dropped selling prices to below $100 per ton. In contrast, caustic prices now are above $300 per ton on the spot market, despite demand being weaker than a year ago.

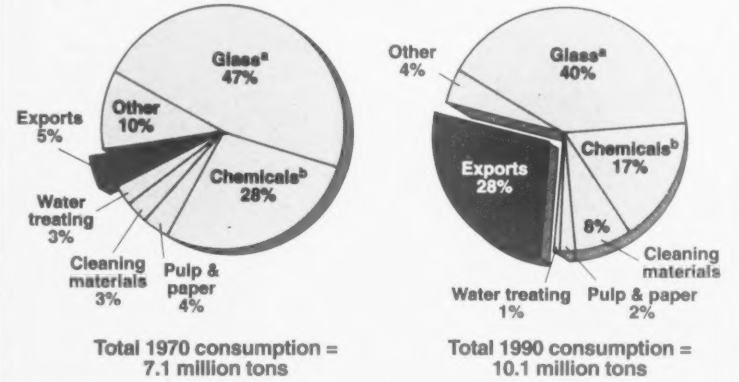
The lime-soda process is based on simple inorganic chemistry. When added to sodium carbonate in solution, lime (calcium oxide) becomes slaked lime (calcium hydroxide), which then reacts to form caustic soda (sodium hydroxide) and calcium carbonate that precipitates. The reaction can be driven by removal of the calcium carbonate through filtration. Cost of the process is reduced by using solution-mined soda ash, such as is done by FMC, or by using mine waters containing soda ash, as done by Tenneco Minerals and expected to be done by other companies starting in 1992.

In most instances, the caustic solution is concentrated by multiple-effect evaporation to 50%, leaving the form of caustic most often sold commercially. The lime value can be recovered by calcining in a kiln. If a low-cost source of lime is available, the calcium carbonate may be discarded as a less expensive option than the investment in and operating costs of a kiln.

Currently, the lime-soda process for caustic is being used on a significant commercial scale only in the Green River, Wyo., area, where most production of natural soda ash occurs. Some of the output is used at the site to make other derivatives. Cost for shipping a 50% solution reduces the area for distribution when competing with electrolytic caustic. Small-scale, on-site manufacture of caustic using shipped-in dry soda ash is not competitive with electrolytic caustic if costs of recovery of the lime value or disposal of the calcium carbonate are included.

Both the lime-soda process and the process to make soda ash synthetically (by the Solvay process or its derivatives) were developed for small-scale commercial use about the turn of the 19th century, and both involve calcium carbonate. In making synthetic soda ash, sodium chloride and calcium carbonate are reacted to make sodium carbonate, lime, calcium chloride, and carbon dioxide. Ammonia and water are involved in intermediate steps of the overall reaction and are then recycled.

As in the lime-soda process, a disposal problem results from the synthetic soda ash process. This coproduct calcium chloride presents an even greater disposal problem than the coproduct calcium carbonate of the lime-soda process. As a result, U.S. companies produce only natural soda ash.



Exports dominate growth in soda ash demand

a All forms. b Bicarbonate, phosphates, silicates, and others. **Source:** C&EN estimates

called cullet. Use of cullet is driven by both environmental concerns and the economics of glass-making. As recycling accelerates, the amount of cullet grows, its quality improves, and its cost goes down, points out Shamel. The quality requirements for flat glass generally limit cullet use to waste glass made on site. Container glass, however, may be made of as much as 50% outside recycled cullet. Some small quantities of recycled cullet also are used in making glass fiber. Recycled cullet probably will continue reducing use of soda ash through the 1990s.

Downsizing or "lightweighting" of containers is another factor cutting demand for soda ash in glass. Reducing glass container weight aims at being more competitive with plastics in shipping costs as well as saving glass. How much more weight reduction of glass containers can be achieved is uncertain, but lightweighting is expected to have a minor effect on future soda ash demand.

Offsetting some of these losses in soda ash use, some companies continue to develop new glass products and new applications for glass containers, says Regan. Examples include the wide range of cookware for use in microwave ovens and the rapid growth in "wine cooler" beverages.

U.S. demand for soda ash in making chemicals—another large market—has remained nearly constant during the 1980s but lost share of total demand as exports' share rose. Soda ash competes with caustic soda for many chemical uses. For certain applications, only one of these alkalies can be used. But for many, substitution is possible. Now, when caustic soda prices are unusually high, soda ash is being substituted where process and handling characteristics allow. That substitution could add 1 to 2% annually to demand for soda ash, industry sources say.

Substitution for caustic could hold soda ash demand for use in chemicals fairly steady, even as demand for some sodium chemicals decreases. Demand for several sodium phosphates is declining, especially sodium tripolyphosphate that goes into detergent formulations, because of more restrictions on use of phosphates in various parts of the U.S. Gains in other small uses of sodium phosphates are not likely to offset the decline in detergents.

Sodium silicates, bicarbonate, and chromate account for most of the other chemicals made from soda ash. Silicate demand fluctuates as detergent formulations change, and as demand changes for various kinds of catalysts, pigments, and other industrial products. Outlook for the bicarbonate may hinge on development of flue-gas treating methods. Demand for most of the chromium compounds made from sodium chromate is expected to be flat. As a group, chemical uses of soda ash probably will not grow much, and the percentage of total soda ash use for making chemicals is likely to decline.

Cleaning products consumed about 8% of soda ash last year. Soda ash is put into detergents and other cleaners to act as a builder, a buffering agent, and a diluent. Changes in formulations of these products can affect demand for soda ash. The average annual growth for this use is about the same as for cleaning materials in general, which is about 2% annually.

Pulp and paper manufacture once required more than 250,000 tons of soda ash annually. By 1982, this use was down to 60,000 tons per year. Because of the high price of caustic, this use has resurged and may reach 150,000 tons this year. But after the resurgence, demand will grow more slowly because the many mills that have facilities to use soda ash will have switched to soda ash.

A large number of other uses account for less than 10% of soda ash demand. They range across most industries, including textiles, foods, metal processing, and flue-gas treating. Demand for soda ash in these uses, possibly spurred by environmental regulations, could grow more than the average because of new developments in a diverse group of businesses.

Use of soda ash in flue-gas treating, for example, continues to depend on response to the Clean Air Act amendments and on competition from other materials selected to remove sulfur dioxide from flue gases. In general, soda ash proves more effective in wet scrubbing of flue gas, but wet scrubbing is more capital intensive and thus is used more in new installations. In dry scrubbing, ores such as trona and nacolite are used as dry sodium sorbents in preference to soda ash for converting sulfur dioxide to sodium sulfate. Despite the concerns over acid rain, industry sources forecast modest growth for soda ash for the near term in this use.

With all of the varied uses, soda ash stands out as a premier example of a mature commodity chemical. Although growth in demand for soda ash will be slow, it will happen. As a result, soda ash can be expected to remain as stable in an economic downturn as it has this year. □